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ASAPH HALL.

H. S. PRITCHETT.

Professor Asaph Hall, one of the most noted of American astronomers, died on November 22 at the home of his son, Professor Angelo Hall, at Annapolis, Maryland, and was buried at Goshen, Connecticut, in the family cemetery on November 25.

Asaph Hall was born in Goshen, Connecticut, October 15, 1829. His ancestors were among the early English settlers of New England and their names appear in the records of the colonial wars and of the revolution. His grandfather, Asaph Hall, was a captain of the company organized at Cornwall, Connecticut, which assisted in the defense of Ticonderoga. His father, Asaph Hall, married Hannah Palmer, of Goshen, Connnecticut, and Professor Asaph Hall, who has just died was the eldest of six children by this marriage.

He received such early education as the youth of his time had access to in the country and at Norfolk Academy and, after he had become of age, attended College at McGrawville, N. Y. There he met Angeline Stickney, a student and teacher of mathematics at that college, whom he subsequently married and who, throughout her life, gave herself devotedly to him and to his scientific work. Professor Hall's choice of astronomy was largely due to her suggestion and she was the first perhaps to recognize his unusual mathematical ability. After their marriage, they went to Ann Arbor, Michigan, where Mr. Hall studied under Brünnow, the well-known astronomer, at that time director of the Ann Arbor Observatory.

Professor Hall's career as an astronomer began at the Harvard Observatory, under William Bond, in 1857. His work there consisted mainly in the routine observatory work, but he quickly became an expert in the computation of the orbits of comets and began to show the admirable grasp of mathematical relations which later on made him an authority in problems of gravitational astronomy.

In 1862 he entered the Naval Observatory as assistant astronomer and in 1863 was appointed professor of mathematics

in the United States Navy by President Lincoln, a position which he retained until retired, under the regulations, in 1891, on the completion of his sixty-second year.

The thirty years which Professor Hall spent at the Naval Observatory were full of fruitful work, both as an observer and in the higher sphere of mathematical investigation of astronomical phenomena. From 1862 to 1866 his work was that of assistant observer with the 9½-inch equatorial, then considered a very large instrument, and consisted in the main of observations of asteroids and comets. In 1867 he was in charge of the meridian circle; from 1868 to 1875 in charge of the 9½-inch equatorial; and from 1875 to 1891 in charge of the 26-inch equatorial, at the time of its erection the largest refracting telescope in the world. During these years he was the leader in many expeditions to distant parts of the world to conduct observations of special interest. In 1869 he went to Bering Strait to observe an eclipse of the Sun; in 1870 to Sicily to observe an eclipse; in 1874 to Vladivostock to observe the transit of Venus, the voyage being made on the *Kearsarge*. In 1878 he had charge of an expedition to Colorado to observe the eclipse of the Sun in that year; and in 1882 he went to Texas to observe the transit of Venus.

The contributions of Professor Hall to astronomy were so numerous that a mere enumeration of them would fill a long catalogue. Working astronomers have been familiar with his papers in the *Astronomische Nachrichten*, that universal journal of astronomical communication, for half a century.

His first discovery with the 26-inch equatorial, which was of great interest, was a white spot on the planet Saturn in 1876, by means of which a new and accurate determination of the rotation period of the planet was made.

In the summer of 1877, at the time of the near approach of the planet Mars, he made a systematic search for new satellites, which was rewarded by the most interesting discovery with which his name is connected, that of the two satellites Deimos and Phobos. Up to that time it had been believed that Mars had no moons and the discovery of two companions of this comparatively well-known planet in a period less than one-third of the revolution time of the planet itself, came to astronomers almost as an unwarranted innovation in the solar system. The investigation of the inner

satellite has led to the most interesting results in the study of the evolution of planets and their satellites.

Next to these brilliant telescopic discoveries, the discovery of the motion of the line of the apsides of the orbit of Hyperion, one of Saturn's satellites, was perhaps Mr. Hall's most remarkable piece of work.

His long and systematic observations with the great equatorial at Washington were of special value, not only for the great accuracy with which they were made, but also for the admirable way in which they were joined to the work of other observers and made as nearly as possible comparable with them. Perhaps no observer in any nation, unless it be Otto Struve, has contributed so long and valuable a series of observations with a single equatorial as is embraced in the work of Professor Hall.

This work lay mainly in three directions: first, planetary observations, consisting in the main of determinations of the positions of the satellites, with the consequent investigations of their orbits; second, observations of double stars with numerous investigations of the double star orbits; third, determinations of the stellar parallax. In each of these fields of astronomical activity Mr. Hall's work was of the highest value and led not only to interesting observational results, but to most elegant discussions of gravitational problems in the solar and stellar systems. His observations, in particular, of the system of the planet Saturn, including those of the rings, have been of primary importance in bettering our knowledge of that interesting planet.

In all this work Professor Hall showed not only a high order of skill as an observer, but he also developed a very high order of ability in his grasp of those mathematical relations involved in the treatment of the gravitational problems of our system of planets and satellites. His papers concerning the various problems arising out of the motions of planets and satellites brought him his highest recognition and showed him to be a man possessing an order of intellectual ability of exceptional character. It is not too much to say that he is one of a group of Americans of not more than a half dozen men at most who have attained high rank as mathematical astronomers.

The recognition of Professor Hall's work by various societies and governments is most significant of the character of the work itself. He received the gold medal of the Royal Astro-

nomical Society of London, the Lalande prize of France, the Arago medal from the French Academy of Sciences, and was made a knight of the Legion of Honor. He was a member of the more important scientific societies in this country and abroad, being an honorary member of the Royal Society in England as well as of the French Academy and of the Roval Academies of Russia and Germany. As a member of the National Academy of Sciences of America he served for many years as secretary and later as its vice-president. He received honorary degrees from many colleges and universities amongst others the degree of LL.D. from Yale and the same degree from Harvard at the celebration of its two hundred and fiftieth anniversary.

Retiring from the Naval Observatory at the age of sixty-two, in accordance with naval regulations, Professor Hall continued his work for some years at the observatory in order to complete those matters upon which he was particularly engaged. For some years after he was in charge of the observatory at Madison, Wisconsin, and in 1896 became a member of the faculty of Harvard University with the title of professor of mathematics, which he retained until 1901.

Professor Hall's first wife, Angeline Stickney Hall, died in July, 1892. Of this marriage four sons survive. In October, 1901, he married Mary B. Gothier, of Goshen, Connecticut, who survives him.

Professor Hall numbered amongst his friends the leading scientific men of Europe and of America. His correspondence, running back for more than fifty years, would form of itself an interesting account of the astronomy of his day. He was in temperament, in devotion, in the simplicity and single-mindedness of his life, a true man of science. For him no distractions of social recognition or money-making served to withdraw his attention from the science to which he had given his life. No man in our generation and in our country has given a better example of that true simplicity and sincerity which are the distinguishing characteristics of the highest type of the scientific life. Those of us who worked with him as students, as assistants, as colleagues, revere his memory not less for the simplicity and sincerity of his personal life than for the work he wrought for astronomy. His career is an illustration of the possibilities open to an American boy, and his life has shed luster upon his country and upon his science.

SCIENCE, December 13, 1907.

HALLEY'S COMET.

O. C. WENDELL.

FOR POPULAR ASTRONOMY.

On account of the importance attaching to Halley's comet and its approaching return to perihelion in 1910, it seems to be a matter of interest at the present time to know its general course of approach to the Earth and Sun. Accordingly I have computed the following ephemeris from Pontécoulant's elements, given in the *Connaissance des Temps* for 1908, for intervals of three months, except those in 1910 which are for somewhat shorter intervals. The last date in the table, May 16, 1910, is Pontécoulant's computed time of perihelion passage.

As a result of the admirable work of Messrs. Cowell and Cromelin in computing anew the orbit and perturbations, as well as the work of others yet to come in the same line, Pontécoulant's elements will, possibly, be somewhat changed, but while the ephemeris computed from those elements and given below, cannot perhaps be assumed to *rigorously* represent the places of the comet on the different dates, yet these places and distances may be regarded, at least as approximately indicating its apparent path.

Date	HALLEY'S COMET								SUN			
	R. A.			Dec.			Millions of miles from		R. A.		Dec.	
							Sun	Earth				
	h	m	s	°	′	″			h	m	°	′
1907 Oct. 1.5	6	53	32.6	+11	14	14	872	876	12	27	− 2	55
1808 Jan. 1.5	6	21	17.6	+10	35	24	815	726	18	43	−23	5
" Apr. 1.5	5	50	1.0	+12	40	42	757	774	0	43	+ 4	35
" July 1.5	6	14	46.7	+14	4	38	696	788	6	41	+23	7
" Oct. 1.5	6	37	52 8	+12	59	51	630	625	12	30	− 3	13
1909 Jan. 1.5	5	42	56.5	+12	14	24	561	473	18	46	−23	1
" Apr. 1.5	4	59	8.1	+14	41	38	488	522	0	42	+ 4	29
" July 1.5	5	35	53.5	+17	21	23	408	498	6	40	+23	8
" Oct. 1.5	6	3	42.3	+17	41	6	319	294	12	29	− 3	7
1910 Jan. 1.5	2	33	21.7	+13	0	23	218	158	18	45	−23	2
" Mar. 1.5	1	8	51.5	+10	32	22	144	202	22	47	− 7	44
" May 16.5	0	44	28.3	+16	51	31	64	94	3	30	+19	1

Cambridge, Mass.

PIERRE JULES CESAR JANSSEN.

HECTOR MACPHERSON JR.

FOR POPULAR ASTRONOMY.

Astronomical science has been heavily hit during the past year by the hand of death. Early in January, there died Miss Agnes Clerke, the astronomical historian who left a place which has not been filled. She was followed in June by Professor Alexander Herschel, the Son of Sir John and grandson of Sir William Herschel. In August there passed away Professor Vogel, of Potsdam, one of the most original men of his time; and now France has lost its oldest astronomer, one of its veterans of science, and is mourning the death on December 23 last of Professor Janssen, the director of the Meudon Observatory, near Paris.

M. Janssen had a long active and brilliant scientific career and his astronomical work was of lasting value. Born in Paris on February 22, 1824, Pierre Jules Cèsar Janssen was in his eighty-fourth year. He was well educated and devoted himself in his youth to Chemistry, Mathematics, Physics and Architecture. It was not until 1864, when he was forty years of age that he became definitely an astronomer. In that year the French Academy of Sciences sent him to Nyon, on Lake Geneva, to study spectroscopic astronomy. Here he threw himself into this branch of the science with vigor and energy. In 1869 he ascended Etna and spectroscopically observed the planets from the summit, detecting water vapor in the atmosphere of Saturn.

But his greatest work was accomplished in 1868. On August 18th of that year there occurred a great total eclipse of the Sun, visible in India. The French Academy sent Janssen to Guntoor to observe the phenomenon. At that time the interest in a total solar eclipses centered round the prominences or "red flames" which had, in 1860 been definitely ascertained to belong to the Sun.

The problem of 1868 was to get more knowledge regarding the prominences. The morning of the eclipse was not perfectly clear, but Janssen succeeded in observing the spectrum of the red flames, which his instrument showed to be one of the bright lines, proving conclusively that they were composed of glowing gas. A brilliant idea struck the French astronomer. He was impressed with the brilliance of the

bright lines from the prominences, and it occurred to him that the spectrum might be observed without an eclipse. As Proctor pointed out in his work on the Sun: "The light of the prominences, when dispersed by the spectroscope forms a few lines; that of the illuminated terrestrial atmosphere is spread out into the rainbow-tinted solar spectrum. Therefore, if we only use adequate dispersive power, we can cause the prominence lines to show conspicuously on the background of observed atmospheric light." After the eclipse was over, clouds gathered, so Janssen was prevented from trying the experiment of observing the prominence-spectrum in full daylight; but at ten o'clock on the following morning he turned his instrument on the Sun and observed all day. "I have experienced today a continuous eclipse" he remarked. He had succeeded in observing the prominence spectrum in full daylight and had made possible continued and systematic observations of the red flames of the Sun.

On September 19, 1868 Janssen announced his discovery to the French Academy, but the news took two months to reach Europe. By that time Sir Norman Lockyer had made the same discovery in England and a short time before Janssen's result arrived, Lockyer had sent to the Academy a communication to a similar effect. To commemorate the discovery the Academy caused a medal to be struck in 1892, on which Janssen and Lockyer appeared as co-discoverers.

Since 1895 Janssen has been director of the Astro-Physical Observatory at Meudon, near Paris, in connection with the Paris Observatory. He secured many remarkable observations of the Sun and published his results in January 1904 in his great solar atlas, which comprises six thousand photographic representations of the solar surface.

That an astronomer's life is not necessarily a dry uninteresting one is illustrated by the career of Janssen, for his adventures in connection with his scientific expeditions bordered on the romantic. At the time of the eclipse of December 22, 1870 he was in Paris and of course the French capital was at that time besieged by the German army; but so determined was Janssen to see the eclipse visible in Algeria that he escaped from the city in a balloon. But his hopes were disappointed, for at Otan clouds obscured his view of the eclipse. In 1894 he observed the transit of Venus at Nayasaki and narrowly escaped destruction by a typhoon in the China seas. In 1888 he traveled about 11,000 miles

to observe a total eclipse at Caroline Island a coral reef in the Pacific, and on this occasion he was very fortunate.

In 1890 Mr. Janssen ascended Mont Blanc to arrange for the erection of an observatory on the top of the ice-cap and three years later at the age of sixty-nine he made another ascent to observe the oxygen-lines in the Sun's spectrum. Latterly he lived quietly in France, but was active to the last.

Janssen was a knight of the Legion of Honor and of the Brazillian order of the Rose, and a Foreign Member of the Royal Society of London. A few years ago France could boast of a group of eminent astronomers whose fame was world wide. Janssen, Tisserand, the brothers Henry, Perrotin, Callandreau, Loewy and Flammarion, within a few years death has sadly depleted their numbers, and now Flammarion reigns alone, the undisputed chief of French astronomy.

Johnsburn, Balerno,
Midlothian, Scotland.

SOME OPPORTUNITIES FOR ASTRONOMICAL WORK WITH INEXPENSIVE APPARATUS.*

GEORGE E. HALE.

I have sometimes heard it said that the great cost of modern observatories tends to discourage workers with small instruments—observers who are no less interested in the pursuit of astronomical research than the astronomers in the large institutions. It seems to me that if there is any serious discouragement, due to this cause, of men who are engaged in original research with small telescopes and inexpensive apparatus, it is a question whether large observatories should be established. For at any period in the progress of observational astronomy there are two most important subjects for consideration. One relates to the accomplishment of a great amount of routine observation and the discussion of results, and the other relates to the introduction of new ideas and to the beginnings of the new methods which will make the astronomy of the future. I think we will all admit that the introduction of new ideas is quite as important as the prosecution of routine research; and that if any cause whatsoever

* A Lecture delivered by Professor Hale, Director of the Mount Wilson Solar Observatory of the Carnegie Institution of Washington, at the Royal Astronomical Society, Burlington House, London, W., on Wednesday evening, June 26, 1907.

tends to discourage the men from whom the new ideas might be likely to proceed, that cause of discouragement should be set aside if possible. And therefore I say, with all seriousness, that it is a fair question whether large observatories, with powerful instrumental equipment, should be established if they tend to keep back the man who is pursuing the subject with less expensive appliances, and is introducing, through his careful consideration of the possibilities of research, the new methods which in the process of time will take the place of the old ones. I think it can be shown, however, that the large observatories should be a help rather than a hindrance, at least by suggesting new possibilities of research, in which most valuable results can be obtained by simple means.

I am talking tonight, in purpose at least, to the amateur; but my definition of the amateur is perhaps a broader one than is generally accepted. According to my view, the amateur is the man who works in astronomy because he cannot help it, because he would rather do such work than anything else in the world, and who therefore cares little for hampering traditions or for difficulties of any kind. The "amateur," then, is the person to whom I wish to address my remarks, whether he be connected with a small observatory in the capacity of professional astronomer, or working by himself with very simple instrumental means. But in speaking to the amateur I do not wish to deal with work that shall be satisfactory merely from the standpoint of instruction or amusement. That is not my purpose. If it is possible to carry on research by simple means that shall really be important and useful, it is my hope to point out some such possibilities. But I do not wish to speak of any work except that of the first class, nor to recommend that any investigation should be undertaken with simple instruments that are not quite as important as other investigations which can be better undertaken with more expensive instruments.

The problem then becomes one of this character—to determine the relative advantages of large and small telescopes for different classes of research, and the possibility of constructing really powerful instruments at moderate expense. I cannot pretend to discuss all phases of this large problem; I shall mention only a few of them, and approach it from a single direction. But before taking up the details of this discussion, perhaps I may be permitted to say that the con-

ception that is sometimes formed of the newer observatories, the idea that vast sums of money are expended, perhaps without the fullest sense of economy, is not always well-founded. For I am quite sure that if you would visit us (to take a single concrete case) in California, you would agree that we have considered the economical side of the question, that we have perhaps in some instances gone almost too far in our desire to save money for instruments of research, and to economize in certain directions where money can be saved. For example, you would find that our offices, our buildings, are of the simplest and least expensive character, while our instruments and machinery are as effective as we can make them. The great expense of such an observatory as the Solar Observatory on Mount Wilson does not depend in large degree on the cost of the instruments used for investigations of the Sun, but in surmounting the difficulties encountered in utilizing a mountain site, deprived of the ordinary means of transportation, and in the construction of large equatorial reflecting telescopes for stellar work, which cannot be built cheaply if they are to be really efficient.

I wish now to come to the question before us, and to illustrate some of the advantages and some of the disadvantages of large and small instruments. Perhaps you will permit me, in showing the first slide on the screen, to say that I have some right to undertake a discussion of this sort, because I have viewed the subject from the standpoint of the man using small and inexpensive apparatus. In my first spectroscopic work, which was done in a room in my father's house, the instruments were of the simplest character, and largely of my own construction. Later, a small building was constructed for a concave grating of ten feet focal length, and the apparatus, although powerful, was not expensive. Subsequently a tower and dome were added, and a 12-inch telescope was erected for photographic work upon the Sun. After the preliminary experiments had been completed, and the spectroheliograph had begun to take form, the possibility that its results could be greatly improved through the use of a larger telescope suggested itself, and for this reason I made many efforts to acquire a large instrument for these solar investigations. The result, through the generosity of Mr. Yerkes, was the 40-inch Yerkes telescope, which proved to be very useful for the extension of the

spectroheliograph work. The next slide shows the instrument, which you will see is a large and expensive machine. The question, then, comes right down to this point: What are the advantages of such a telescope compared with, let us say, a 6-inch equatorial or possibly a 4-inch equatorial? It is possible with a 6-inch equatorial to do the work comparable in importance with the work that can be done with a 40-inch equatorial?

The next slide will show that there was an advantage in passing from the Kenwood 12-inch to the Yerkes 40-inch, at least for the photography of the Sun. Very minute details of the flocculi were brought out which had not previously been known. But it may easily be shown that the advantages of the 40-inch telescope for most classes of solar work are due more particularly to its great focal length than to its large aperture.*

Let us take another illustration. Here we have a picture of the Moon made by Professor Ritchey with the 12-inch Kenwood telescope. You will notice that near the terminator is the crater Theophilus, which you will see again in the next slide as photographed with the 40-inch telescope. This photograph taken by Professor Ritchey is probably as good a photograph of the Moon's surface as has yet been made, and in this case the advantages of the 40-inch telescope is apparent.† But if we take another case, as illustrated in the next slide, it becomes obvious enough that for certain classes of work the Yerkes telescope is not well suited. Here is a picture made with the 40-inch of the Andromeda Nebula. You see how little it shows, since a long-focus telescope, unless of very great aperture, is not well adapted for the photography of faint nebulæ. When we compare this picture with the next one, made by Professor Ritchey, with the 2-foot reflector (of 8 feet focal length), we appreciate immediately that the 40-inch, in spite of its great advantages for certain classes of work, is wholly unadapted for other investigations. As you know, a refractor of much smaller aperture and of shorter focal length would also give a pho-

* So far as resolving power is concerned, an aperture of eight inches would be sufficient to permit the smallest known details of the flocculi to be photographed.

† Here, again, the full visual resolving power is not utilized, but the great aperture is of advantage in permitting the large image to be photographed with very short exposures.

tograph of the Andromeda Nebula far superior to anything that could be taken with the 40-inch.

If we look at the next slide, which shows Professor Barnard's 10-inch Bruce telescope when it was mounted on Mount Wilson, where he was using it to photograph the Milky Way, you will see an instrument that is very small and inexpensive as compared with the Yerkes telescope. It has a 10-inch Brashear lens of 50 inches focal length and certain smaller cameras attached to the side of the tube. With such an instrument as this, superb photographs of the Milky Way, like the one, illustrated in the next slide, can be taken, which are indispensable for investigations on the distribution of stars in this part of the heavens. Excellent work can also be done with a much smaller lens, provided with a very simple mounting.* A fine instance of systematic work with a portrait-lens is afforded by Mr. Franklin-Adams's photographic map of the northern and southern heavens.

It is hardly necessary to recall the fact that the 40-inch could not do this work at all. If we attempted to photograph the Milky Way with it, we might get a very small region on a very great scale, but to give us any notion as to the general distribution of stars in the Milky Way the 40-inch would be a total failure. However, if it were a question of studying some star cluster like the one shown in this slide, which would occupy a very small region indeed of the Milky Way, the 40-inch would enable us to pick out the separate stars, to study their individual phenomena, their changes in light and position, while such work could not be done on photographs taken with a portrait-lens.

I have shown these miscellaneous illustrations for the purpose of emphasizing, what is perfectly well-known to all of you, that each instrument has its particular fields of work, in which it can accomplish, or permit to be accomplished, various investigations which are not within the reach of other kinds of telescopes. But I now wish to discuss the question somewhat more specifically, and in doing so I shall confine myself almost entirely to observations of the Sun, although one might attack the subject from many other directions. The first point is this. Suppose one has a small

* Professor Barnard has illustrated in the *Astrophysical Journal* some of the admirable results he has himself obtained with a cheap "lantern lens" belonging to an ordinary stereopticon.

telescope of four inches or six inches aperture and wishes to observe the Sun with it; and let us assume at the outset that he has no attachments whatever in the form of spectroscopes, but that he wishes simply to make direct observations of the Sun: Is there work for such an instrument at the present time? If you will examine the literature of the subject you may perhaps be surprised to find that many years have elapsed since very careful and extensive investigations have been made similar to those of Langley, which may be almost forgotten by many astronomers, but certainly are not forgotten by those of us who follow the Sun and are accustomed to the appearance of the spots when the definition is good. The next slide shows the well-known drawing of Langley's typical sun-spot. You will remember, if you have systematically observed the Sun, that every time the conditions become extremely good, the structure of sun-spots more and more closely resembles this drawing. This is a typical drawing; it does not represent any particular spot; it brings together observations of various spots; but in general the details of a sun-spot look very much indeed like that drawing when the definition is good enough to show them properly. This subject has been greatly neglected for a long time, and it would well repay observers with large or small instruments to observe sun-spots, and to study many of the details of their structure which still remain obscure and difficult to understand.* Of course the question of the resolving power of the instrument must then be considered. A 4-inch telescope, capable of separating objects one second of arc apart, would not do for the very finest details in a sun-spot. According to Langley, the penumbral filaments sometimes exhibit structure considerably smaller than such a telescope would show; but a 10-inch or 12-inch telescope would show everything that has ever been recorded in a sun-spot, and there are many instruments of that size available for such observations.† Even a much smaller telescope, if carefully and systematically used, would contribute largely to our knowledge of sun-spots and of

* For example, it would be of great interest to study the structure of the umbra, as seen through a minute pin-hole in the focal plane of a positive eyepiece, as Dawes did many years ago.

† It must not be forgotten that photography is still far behind visual observations in revealing the minute structure of sun-spots. It can hardly be doubted, however, that if only the umbra and penumbra were permitted to fall on the plate, and the exposure properly regulated, new and valuable results would be obtained. The amateur will readily find many opportunities for work in this field.

the structure of the solar surface. One might enlarge upon this subject, but time is hardly sufficient to permit me to do so.

To be concluded.

BRYANT'S HISTORY OF ASTRONOMY.*

The announcement of the appearance of a book entitled 'A History of Astronomy' not unnaturally suggests the question whether there is in our shelves a gap which this book can be expected to fill. *A priori* we should answer in the negative; *a posteriori* we frankly modify that answer into the advice to make a gap for it. We do not for a moment suggest that Mr. Bryant's book should displace Delambre or Grant nor even Miss Clerke; those are in a different category. Perhaps Mr. Berry's 'History of Astronomy' enters more nearly into competition with the book before us; but there is a clearly marked divergence in the aims of the two books, inasmuch as the former has compiled a book of reference for students, while Mr. Bryant has aimed at a lightly written history for the delectation of amateurs.

And to the amateur the book can be cordially recommended. He cannot fail to feel that he is listening to a man who is in possession of full and practical experience of his subject. And perhaps it is just the practical details which will be found the most interesting, such as the chapter on Adjustment of Instruments, in which some account is given of the inevitable difficulties connected with personality, or in such *obiter dicta* as the following:—"Herschel was probably the first astronomer who considered his eye as part of the observing instrument, and was careful to adjust the position of his head in order to view such an object as a band on a planet in the same direction relative to the position of the retina." We hear so much about the science of astronomy that these references to the art are refreshing.

The illustrations naturally catch the attention as one opens the book; the selection is made with determination; the one or two old friends are welcome, while the four from Hevelius are well worth reproduction. It seems a pity to have omitted that one of Hevelius' comets of which the tail is discontinuous; such an anticipation of Barnard's photographic discov-

* By W. W. Bryant, B. A., F. R. A. S., F. R. Met. Soc., of the Royal Observatory, Greenwich. Methuen & Co. Price 7s. 6d.

ery of shattered tails deserves attention. A word of praise is due to the careful account given of the origin of each illustration; the "Newton" by Kneller must surely be well-known. We believe it is now hanging at Petworth. It is annoying, however, to find the photographs of nebulæ indiscriminate in their orientation. The Pleiades have the north at the top, the Ring Nebula has the west at the top, and the rest have the south uppermost.

The style of the whole book is light and pleasant and induces one to forgive an occasional obscure passage. Sometimes, however, the obscurity is such as to baffle all attempts at comprehension. There is a sentence on p. 163 in which "the axial rotation effect" in the Sun is apparently made to account for "well-marked frequency zones for spots," and another on p. 31 containing reference to "the practically infinite distance of the point to which the Earth's axis is directed." We confess that these defeated us.

Perhaps the greatest difficulty that the critic finds in estimating the success of the book consists in arriving at any idea as to the class of audience that is being addressed. On p. 15 the obliquity of the ecliptic is carefully explained, while on p. 59 an argument such as (5S—2J) is lightly referred to and seems to call for no enlightening footnote. One cannot help sympathizing with an author who is full of information; it costs a pang to omit anything, but there can be no question that there is too much in this book. With p. 125 open before us we find that there might have been eleven footnotes, all giving reference to first class papers. Such a page cannot leave any useful impression on the mind. Difficult subjects like the interpretation of spectra are treated so sketchily that the account can scarcely be useful to the unenlightened, while it is superfluous for others.

The biographical part, covering the first 96 pages, suffers least from the congestion which mars so many chapters. Surely Copernicus did think that the stars were all the same distance from the Earth; and ought not a special reference to be made to Tycho's initiation of the important practice of repeating observations? "Tycho next married a plebian girl on his own account," which is called a "descensus Averno." In passing we cannot omit to note with satisfaction that both in the case of "Averno" and of the "smaller fleas" later in the book, common misquotations have been avoided. Hevelius should have the credit of the optical libra-

tion, while Galileo claims the diurnal. Can Mercury have been seen in transit before Kepler's time, that is without a telescope? We must test this on the 14 inst.

Three chapters on the Sun are full to overflowing, but the interest is well maintained in spite of several exceedingly cryptic passages.

In the five chapters on the stars the impossible task has been attempted of covering the whole ground from Fundamental Astronomy to Spectroscopy in 70 pages. But when once we have asserted the impossibility, we must admit that the reader finds it difficult to put down the book, the matter is so clearly sound, and the manner is cautious and philosophical. There is a pleasant absence of dogmatic statement; in fact the fault is rather in the opposite direction. Such phrases as "it is hinted that" might often be replaced by a more direct assertion. We are, for instance, told that it is doubtful whether the lunar rills are or are not dried-up water-courses, when the negative has been asserted by more than one competent authority. Dr. Rambaut has done more than "hint" that he can produce the green flash before sunset. Again, we read that the case stated by Kapteyn and Eddington might be "met by assuming for our system a position well outside the center of a single universe, so that a fair proportion of its members by virtue of their position, like planets at inferior conjunction, would appear to be moving in a different direction to the rest." This suggestion has been disposed of by Mr. Eddington as ignoring the whole principle of his discussion.

The index is well compiled, and the marginal cross-references if continued throughout the book would have greatly added to its usefulness as a book of reference. The pages on bibliography and current periodical literature are useful, and would have been more useful still to the uninitiated had some guidance been given as to which of the periodicals might perhaps have been suited to him.

The proof-reading has been exceptionally careful; we find one hyphen displaced on p 342!

For an extremely ignorant and for the extremely learned in Astronomy the book is not suited, but for that very reason it will probably meet the requirements of many among that larger public who fall between those two extremes.

J. A. H. in *The Observatory*, November 1907.

THE "AUTOCHROM" PLATE.

ROBERT JAMES WALLACE.

For Popular Astronomy.

It is difficult to introduce this subject without a prelude upon the happy realization of the many hopes which have been entertained since the advent of photography, regarding the registration of objects in their natural colors. It may be, however, sufficient to state, that hope sustained by many promises has at last been realized, if not in a manner thoroughly complete, yet sufficiently perfect to warrant high commendation.

During the past few years there has been great activity in the direction of "color photography;" an activity, which not confined to any one country, has produced many processes and methods possessing in the main undoubted merit, yet they have but rarely advanced beyond the position of interesting laboratory experiments.

It has been reserved however, for Messrs. Lumière, of Lyons, France to produce and place upon the market, a one plate method which places in the hands of even the ordinary amateur the means of reproducing in full color, and with a single exposure, a record of the object photographed, in all its varied tints and tones, and with a fidelity truly marvelous. That the Messrs. Lumière should have brought the plate and method to such a point of perfection before its public introduction, is an achievement deserving of much praise.

The "autochrom" plate consists of a plate of glass of fairly even quality, upon which is spread a layer of colored potato starch granules. These transparent granules are colored respectively red, green and blue-violet, and are then mixed together in quantity, in proper proportion; and spread over the cleaned and varnished plate, and then rolled to flatten the granules. The interstices between the circular colored disks are then filled by a black pigment, thus preventing the passage of any light other than that which passes through the colored starch grains.

After again varnishing, this colored mosaic filter layer is coated with a film of "panchromatic" emulsion, and the plate is complete.

Exposure must be made through the "back", so that the light is compelled to pass through the colored granules before

reaching the sensitive film. It is necessary also, that the light must pass through a yellow compensation-filter placed in front of, or behind the lens, its purpose being to absorb the ultra-violet, and reduce the action in the visible blue and violet.

After exposure the plate is developed with pyro-ammonia, and after a brief washing, the reduced silver, i. e., the negative image, is dissolved out by means of acid permanganate of potass, and redeveloped, thus obtaining a positive image in place of the former negative. The plate now shows clear film proportionate to the amount of silver reduced, and through which regions may be seen the color of the starch granules. Intensification, clearing, fixing, washing, drying and varnishing, follow in rapid succession, details of which are supplied by the Lumiere company together with the plates, and which need find no place here.

Taking up first the colored layer, a microscopic examination gives the granules a mean diameter of 0.014mm.,* and which with polarized light, show the characteristic black cross. With the aid of the spectroscopic eyepiece the absorption spectra of the individual colors may be observed. Photography of the spectrum, however, supplies all the information necessary upon this point, and to which further reference will be made presently.

By counting the colored granules contained in various selected areas, one may reach a conclusion as to the relative distribution. From this observation it results that the red, (or blue) granules are about equal in number, while the green are in excess in the ratio of about four green to three red and blue. Treatment of the color film with hot water (temp. 90° C.), and occasional examination under the microscope, shows that the blue color is the most soluble, next the red, while the green granules retain their color for a considerable length of time. Evidence of the greater solubility of the blue-violet is shown by the general yellow tint which the plate acquires after but a very brief immersion in the hot water, which indicates the removal of the blue-violet color in quantity too small to be indicated by examination of the individual granules. Upon treatment with cold water the green granules appear to be the first to discharge their color, followed by the red, while the blue appears to be quite persistent. No difference could be observed in the mass tint after soaking in cold water for thirty minutes. Ether dissolves the varnish

* This is in practical agreement with Wall who gives a mean of 1.5 mm., Brit. Jour. Photo. Sup. p. 57, 1907.

of the starch layer so that isolated granules may be observed individually; there is no influence, however, upon the color. In alcohol the green color is slowly discharged and the color film frills away from the glass support in one continuous sheet. Dilute ammonia discharges the color slowly in the order of red, green and blue. In acid permanganate of potass all colors are equally (but slowly) discharged.

Measurements to determine the absorption coefficient of the color-film and glass, made in the polarizing spectrophotometer,* gave a mean value of 16.6° which equals a H. & D. density of 1.0882. Measurement of the thickness of this colored starch layer gives a value of $\frac{6}{10{,}000}$ inch $= 15.24\mu$.

The sensitive film which is coated upon the color filter-layer is of extreme tenuity measuring in thickness slightly less than 4.0μ ($= .00015$ inch). With the ordinary dry plate film of Seed "27" there is a measured thickness of about 31μ ($= .0012$ inch). This extreme thinness of film precludes the consideration of much latitude in exposure, and this is borne out in practice. The sensitive film itself is not entirely soluble in hot water, nor does it dissolve in an ether alcohol mixture. Stenger† is of opinion that the sensitive film is composed of a combination of gelatine and collodion, which, from the observations of the writer, is considered as probable, even although the further treatment with ether-alcohol failed to dissolve it. The reduced "silver grain" of this film is of exceptional fineness for a fast emulsion, giving upon measurement a mean of 0.5 to 0.8μ for individual "grain" particles, while mean "group particles"‡ measure 1.6μ to 2.0μ; these measurements were of course made prior to intensification.

Tests for determination of selective sensitiveness were made by exposing an "autochrom" plate with the film side towards the lens, to a series of nine differently timed exposures to the spectrum of diffused daylight, in the "standard" spectrograph,¶ the sky effect remaining apparently constant throughout. Examination of the resultant negative (devel-

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* See *Astrophysical Journal* 25, 124. 1907. Studies in Sensitometry I. by the author.

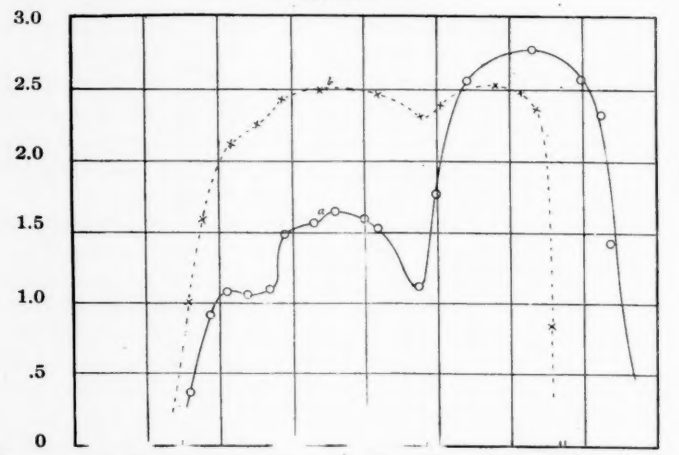
† Zeitschrift für wissenschaftliche photographie. Band 5. p. 374, 1907.

‡ *Astrophysical Jour.* XX p. 113. 1904.

¶ For description of this and other instruments for sensitometry see former paper *Astrophysical Jour.* vol. 25. p. 122. also vol. 26. p. 12. 1907.

oped in pyro-ammonia) shows a heavy drop in the blue-green sensitiveness, which extends from λ 4860 to nearly λ 5180, (F—*b*). A second drop is apparent from λ 5890 (D) to λ 6200, the sensitiveness ending (with normal exposure) at about λ 6500 *minus*.

FIGURE 1



[The vertical of G lay so near to the line "4300" that it coincides in the reproduction.]

From measurements on this plate, the accompanying curve figure 1 (*a*) was plotted, and examination of which shows that regarded from a "panchromatic" standpoint the emulsion leaves much to be desired. The sensitiveness-curves shown herewith are not in agreement with those plotted by Stenger who shows a much higher χ value $\left(=\frac{\lambda\,4100}{\lambda\,5600}\right)$ than does the present writer. In Stenger's sensitiveness-curves the density value of the red at λ 6100 is almost identical with the density of his blue at λ 4200. The lack of accordance arises from the fact that Stenger made use of an artificial light source (Nernstprojektionslamp) which gives a false intensity to the red, while the present curves are from negatives exposed to a gray foggy north sky.*

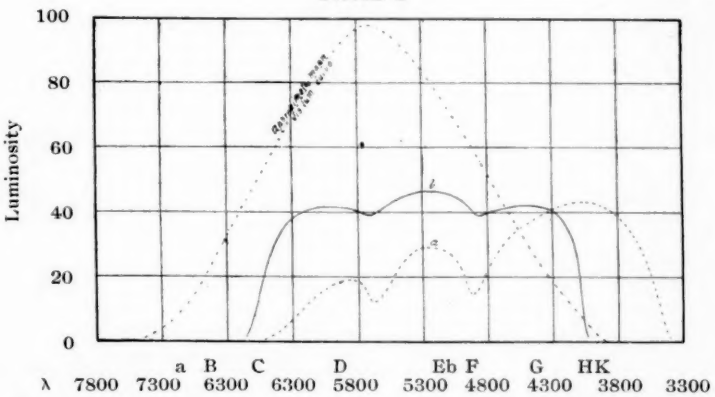
Exposures were also made upon the film side through the Lumière compensation-filter, and the effect obtained is shown

* (Die Autochromplatte Erich Stenger. Zeitschrift für wissenschaftliche photographie. 5. 376. 1907.)

by the dotted line (*b*) in the same figure. The rather abrupt drop in the blue-violet, and the general improvement in the orange and blue-green will be readily noted. The adjustment of this filter evidences much care, and it would be indeed difficult to improve upon, either in individual or commercial manufacture.

A series of spectrum exposures were now made with the light passing through the color film but *without* the interposition of the compensation-filter. The plate was handled throughout according to the instructions by Messrs. Lumière. With underexposure the action is first visible in the violet at λ 4100, which, as it is to be expected, is shown as a bright blue, while with increased exposure the green at λ 5270 is the next color to show, followed almost immediately after by an action at λ 5850, which region is shown as a deep red instead of a bright yellow. With increased exposure the blue-violet from

FIGURE 2



λ 4300 to λ 3900 becomes diluted with white, while the green and red regions are extended and brightened, but showing at what may be termed "normal exposure," two distinct absorptions in the blue-green and yellow as indicated in *a*, figure 2. The ultra-violet region to λ 3400 is of course evident throughout, and is shown as a bright blue.

There is difficulty in depicting graphically the "autochrom" reproduction of the spectrum, inasmuch as the colors do not correspond correctly to the wavelength. For example, taking the blue region from λ 4860 (F), to λ 3933 (K) in the ultra-violet, visual observation of the spectrum show that the hues

embraced are pure blue, indigo blue and violet. In the "autochrom" reproduction on the contrary, we have first a drop in the blue at F, just where it should show the purest, which is due, first, to the insensitiveness of the emulsion for that region and second; to the lack of overlap (with normal exposure) in the green and blue filter transmissions, which results in the introduction of black at this point, hence a lowering of the luminosity curve. The change in hue with the wavelength which gives the delicate blend to indigo blue and then to the spectral violet, is absent in the reproduction, being represented instead, (after recovery from the insensitive band at F) as a blue of even hue throughout. The same criticism applies to the green and red regions. That delicacy and charm of graduated color which makes the solar spectrum the most magnificent phenomenon in the domain of science is utterly lacking in the reproduction, which appears crude by comparison. Hence in the graphical representation of the colored spectra, be it understood that approximate luminosity alone, is estimated, and not hue.

A second series of exposures made through the color film of the plate, but with the interposition of the compensation filter, presents particular interest, as not only fulfilling the requirements demanded by the inventors, but as supplying authoritative information relative to the selective transmission of the color granules. With underexposure the region at λ 5850 is the first to show action but instead of being represented as a pure yellow is again depicted as a deep red. This is to be expected when we consider that the additive formation of yellow is accomplished by the mixture of red and green, and that therefore yellow can only be represented when there has been sufficient exposure to extend and unite the action of the red and green regions.

The initial action in the red is closely followed by that in the green at λ 5270 and then by the blue at λ 4500. Increase in exposure results in a widening of the color bands but without perceptible change in hue or purity (although the luminosity is increased), until at "normal exposure," that is to say, at the exposure which represents the maximum allowable, without the introduction of white to the colors there is formed by the mixture of the green and red bands, a rather dingy orange-yellow, in place of a pure yellow of high luminosity. In the opposite direction the admixture of the green and blue color bands results in the formation of an "indigo" of low

luminosity in place of a pure blue-green, together with a faint trace of overexposure in the blue at λ 4400 — 4500. As a reproduction of the spectrum the result is not good, and can be considered as a rough approximation while the size of the color particles (which in this consideration is equal in effect to coarseness of "grain,") precludes the registration of all but the more prominent Fraunhofer lines which are therefore to a large degree, independent of the slit-width; for, when it is remembered that the action throughout either of the three color regions is composed of (almost solely) color particles of one hue, occupying therefore less than one-third of the area,* we see that practically we are reduced to the necessity of considering the result as formed by "group particles" of "grain," of about sixteen times the size of the "grain" particles of an ordinary fast plate.

Even with extreme overexposure it does not appear possible to obtain a pure yellow and this is corroborated by results in ordinary copying where the yellows lack luminosity. From the curve shown in *b* figure 2, it will be seen that the limits of the visible spectrum are much restricted, being cut off rather abruptly (with normal exposure) at λ 4150 and λ 6500. The effect of increased exposure is the formation of a pinkish white, showing first in the regions corresponding to the primary action with underexposure, and, with increase of exposure, extending in the same manner as does the color effect.

The spectrum result obtained by the action of the light through both the compensation-filter and color-film, is, of course, a record of the transmission of the individual color filters which form the mosaic layer. As has been pointed out by Abney† the filters show isolated transmissions, with decided overlap as exposure is increased, and occupying a position midway between the theoretically perfect "taking" and "viewing" filters. As a reproduction of the spectrum the "autochrom" is ridiculous, while in practice, in the copying of multicolored objects, the results are truly marvelous in their fidelity.

Copies of various color-charts were also made, and when the exposure was such that white was reproduced with the closest approximation, examination of the individual color patches show the great difference in results dependent upon

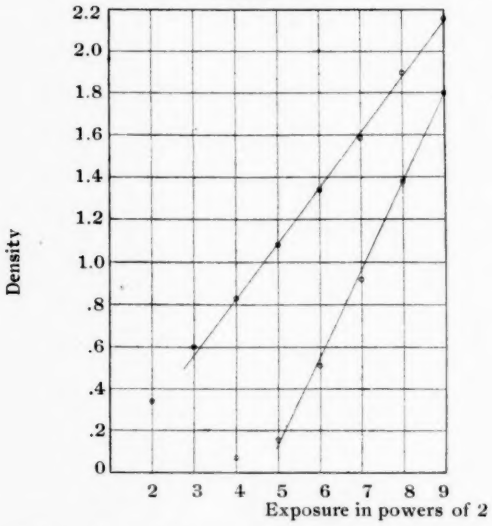
* The black blocking out pigment must also be considered.

† Autochrome. Sir W. de W. Abney. Jour. Royal Photo. Soc. 37, 252, 1907

the photography of *pigment* colors as against *spectral* colors. Under the microscope the yellow region of the spectrum reproduction shows the action confined entirely to the red and green granules, the blue granules being represented by black, while in the case of the reproduction of the yellow pigment patches, the blue granules are also easily visible. The result is a strong uplift to the luminosity of the yellows by the introduction of white.

Inasmuch as the highest light obtainable upon the plate is represented by the admixture of the three colors plus the black pigment it will be seen that white is existent (in re-

FIGURE 4



production) simply as an effect of contrast. The reproduction, therefore, of any colored object is equivalent in truth, to viewing that object through a light neutral gray glass.

Simultaneous exposure of two "autochrom" plates in the revolving sector-disk machine to diffused daylight, (a) upon the face of the sensitive film, and (b), through the color film, give upon measurement, practically identical gradation curves.* While the exposure of an "autochrom" plate (film side) and a Seed "27", give measurements, which being plotted, result in the curves shown in figure 4. Duplicate

* Development of both plates was with pyro-ammonia for two and one half minutes at 20° C.

plates supply confirmation of the higher density factor of the "autochrom" plate for short development, although with lengthened development these conditions are reversed. The extraction of the relative speed difference gives a value of $2^{2.2}$ (= 4.49 times) in favor of the "27". For the total speed difference however, there must be added the absorption-coefficient of the colored layer and glass, and also the multiplying factor of the compensation-filter which reduces the total speed value of the plate to one-sixtieth of the Seed "27".

To one who has worked with the problem of color reproduction by means of superposed films the first view of an "autochrom" is somewhat disappointing in so far as brilliancy is concerned, but when allowance is made for the reduction in luminosity, (which practically amounts to a lowering of the entire tonal scale) the charm of the result in the delicacy of portrayal is a source of growing enthusiasm.

One is led at first sight to rather dread the somewhat extended operations necessary to the production of the finished result, and this fear is rather enhanced by the amount that has been written regarding the tendency of the film to "frill" and thus ruin the result. Personal experience, however, leads emphatically to the statement that the process is really absurd in its simplicity when compared with other methods, and in the hands of the writer, absolutely no trouble was experienced with "frilling", and that although all of the exposures handled, (about fifty), were upon plates which had been cut from larger sizes. It takes in the neighborhood of from twenty to twenty-five minutes (from the time of the completion of the exposure), to produce the finished result.

The value of the plate to the astronomer or spectroscopist is at present not apparent to the writer, but, to the student of photographic science, and to that great body known as "general workers" there has been placed ready to hand, a means of reproducing the many hues of art or nature, by a method whose exquisite beauty calls forth nothing but the highest enconiums.

Time will, of course, bring many improvements, but the process even as it stands now, is a lasting monument to the capability, perseverance, and commercial enterprise of *M. Lumière & ses fils.*

Yerkes Observatory.
December 30, 1907.

METEOROLOGY ON THE PACIFIC SLOPE.

JEROME S. RICARD.

FOR POPULAR ASTRONOMY.

We have of late been engaged in a study of absorbing interest trying to put together the results of our helio-meteorological observations during June, July and August of the present year. In publishing these results, it is not our intention to influence any one this way or that way, much less to descend into the arena of controversy. We are indulging in no theory, but solely looking for and stating facts when we have found them; and if any theorizing there be, it must be a necessary deduction from scientifically ascertained fact. In the sphere of the contingent where meteorology lies, the inductive process takes the lead and the deductive follows.

When this observatory was established, we placed it at the service of the Weather Bureau authorities, under whose fostering care it has remained ever since. Far from being opposed, it has always received from the same authorities not only valuable material help, but also kind encouragement and wise direction. But it was understood, at the very outset, that the great desideratum was not so much a further accumulation of weather records, as philosophical investigation into the origins of meteorological change.

A directive principle along that line of study was that in every system, the primary rules the secondary. The solar system was to be no exception until that exception was proved. The problem had to be faced, not in part but in whole. The meteorologist had so far been mostly concerned with the atmosphere, its temperature, its moisture, its weight, its movement, its electrical loads and discharges. The astronomer, on the other hand, was studying the phenomena of the heavenly bodies, direction, distance, position, interdependence through gravitational agency, physical changes and chemical composition. But the two sets of students kept, on the whole, entirely separate from each other and never thought earnestly of bringing their forces together; and so the link between system and system and, what is worse, the very links by which one system hangs together, were ignored and lost sight of.

But now how changed is the scene! Astrophysics including solar physics has stepped to the front and the high fence between meteorology and astronomy is torn down. The work

so happily initiated by Sir Norman Lockyer in 1871 is taken up to-day by such savants as form a nucleus of the International Society for Solar Research of which Professor Hale of Mount Wilson is the President. The interdict so gratuitously put on the sun-spot is lifted and the suspected link between solar condition and weather condition is one of the fundamental subjects of study adopted by that society. Henceforth the air man and the star man can occupy the same chair and their respective offices be combined.

In the presence of this welcome change, one should naturally expect that the masterly minds of our Weather Bureau would collect their forces and their lights and focus them where there is a hope of snatching her secret from nature—the cause behind the cause. There is a groan heard everywhere that our system of Isobars and Isotherms, as figured forth in that international institution called the Weather Map, is nearly exhausted and barren of ultimate progress. The perspicacity of the well drilled mind is not yet able, by an inspection of the map, to tell whether a low that has appeared over Alberta or Washington will travel southward and bring refreshment to a parched vegetation, and far less is the same mind able to foretell the appearance of that low, and far less again whether it will move north, or south, or centrally.

When beset with such difficulties, who is there who would not sigh after superior methods of forecasting? This is precisely what the representative men of our Weather Bureau are striving with might and main to do. They have installed a great observatory on Mount Weather, Virginia, where the study of solar change, as the cause of weather change, is the main study and the prime consideration.

At the Santa Clara College Observatory, too, and at the suggestion of a prominent Weather Bureau authority, similar work has been in progess. The plan of the work and the method of observation were entirely left to our own choice. So we naturally fell in line with the astrophysicists. With recording instruments checked by non-recorders, we have these six years taken a continuous record of weather change and, with an equatorially mounted 9-inch glass by the elder Clarke, a practically continuous record of solar change.

By juxtaposing and correlating these records, it becomes impossible not to notice certain coincidences that excited curiosity and formed the basis for further, and more accurate observation. It was not, however, until the beginning of last,

spring that we, hesitatively, formulated the following laws:—

1) When a solar spot is within 2, 3 or, at the most, 4 days from the western limb, it produces a warm wave which expands the air somewhere over the Pacific slope or rather west of it over the Pacific Ocean, thereby originating a low; and by referring to the weather map, you will see the area of that low, generally over the northwest during the winter, generally over the valley of the Colorado during the summer. A central low is the exception and that exception baffles the forecaster for tomorrow's weather. He said fair, and behold it rains.

2) If when a solar spot is thus nearing the western limb, other spots rise anywhere on the visible solar surface, the effect is to swell the actual pulse of the temperature, and the swelling is proportional to the size and intensity of the disturbed solar area.

3) When a solar spot is passing or about to pass off the western limb, it produces a cool wave or fall of the temperature pulse. This wave contracts the expanded air somewhere over the Pacific slope or rather west of it over the Pacific Ocean, thus originating a high that the next weather map will register in the proper place. Following the approach of the cool wave, there will be condensation and precipitation. It is plain, however, that the mere cold of a night or the mere cold of the air in the upper regions can do that, whenever the saturation point is reached. But as watery vapors abound especially over and about the area of the low, as the result of the warm pulse, hence whenever and wherever it is cold enough, rains or other forms of precipitation accompany the passage of the low and vanish soon after the coming in of the high by a sheer process of exhaustion.

4) The cool wave occasioned by the disappearance of a solar spot behind the western limb can be, and often is, tempered or neutralized by the near approach of another solar spot to the same limb. This is a mere corollary of laws 1 and 3. Another corollary is that, contrary to a prevailing opinion, solar spots are an index of an excess of solar heat, whether it be that they are hotter in themselves or there is that about them which is intensely hotter than the rest of the photosphere. A great Irish specialist has it that in the sun-spot the carbon is vaporized and incandescent, whereas in the other parts of the Sun the carbon is incandescent, but not vaporized. So, too, thinks another great specialist on the

Sun, Professor T. J. J. See of the Mare Island observatory. Sir Norman Lockyer admits the fact that the sun-spot is hotter, but explains it in a somewhat different way. In that case, the deep violet-blue color of the umbra must be due to carbon vapors.

Since the time when these laws were formulating themselves in our own mind, they have been subjected to a severe scrutiny. But the search for an exception has been in vain, so the reader may rest assured that these new tenets of solar physics are not the offspring of a morbid imagination, but rest on the solid rock of observed fact. We are told: Beware of coincidences. To which we reply: Beware of asking too much. All that a strict scientific induction requires is a sufficient enumeration of observed particulars backed by an axiom or principle that shall lend universality to the conclusion. For as nothing can give nothing, so no particular, as such, can give the universal. Hence no enumeration of particulars, howsoever far produced, can, if incomplete, yield a universal conclusion. Induction that does not go on a universal principle is as bad as a cork leg or a wooden horse.

To illustrate:—By what right do you hold that fire burns? You say all the fires you have seen did burn. But you have not seen all fires, nor will you, nor can you. How can you hold that all fire burns? You say: howsoever that may be, I am positive all fire burns. But again, what makes you so positive. Possibly you can not tell and possibly I can. If you think of the matter at all, you might reason somewhat like this: If every fire I have seen and every fire I have touched, did burn, this thing cannot be accidental; it cannot be mere chance or ill-luck: it cannot be an independent sequence or mere coincidence in point of time, without any internal nexus whatever. Whatever happens by chance, whatever is a mere sequence with no causal nexus, follows no rule; you can never depend on it; it may happen, it may not happen: you are always at a loss to tell whether it will or whether it will not. If you say it will happen or it will not happen, you knowing only too well you are indulging in absolute guesswork.

So the golden principle to go by in these perplexing matters, is the constancy and uniformity of nature. If an event constantly and uniformly follows upon another, this other must be the cause and the two events must go together as cause and effect. Hence it is manifest that for a valid scientific induction, we have only to know a certain number of partic-

ulars, this number being of its nature indefinite, and then apply a universal principle to the point of which there may be question, and, that way, we obtain a universal inference that a strong-headed one may howl against, but can not logically deny.

Such is the train of reasoning that has been followed at this observatory touching the matter of helio-meteorology. We have had cases innumerable of coincidences between approaches of solar maculæ to the western limb and warm waves over the Pacific Slope; and again cases innumerable of coincidences between disappearances of solar maculæ off the western limb and cool waves over the Pacific Slope. We ask any reasonable man what was to be our conclusion, according to the logic of Lord Bacon, or that of Aristotle, or that of any other great thinker? Would he cry out, as some have done: "All mere chance happening—undiluted moonshine—the work of an advanced scholar in noodledom—all humbug!"

But far otherwise have we been taught philosophy; and if that philosophy is wrong, we dare submit there is very little known truth in this world and we are wallowing in the mire of partial or universal skepticism. So we argue that if this whole thing is mere chance happening, and the forecast based upon this thing is mere guesswork, howsoever lucky it may be, the unbroken thread of coincidences must break asunder and there must be a big smash-up somewhere. But this has not been; therefore it shall not be. Therefore there is a causal nexus.

If we are asked to produce our records, we may quote the following for June, July and August of this year—the three most unfavorable months for salient weather features over the Pacific Slope—those very same months about which we were told the solar markings were hors de combat in their hospital home. We have had disappearances of solar spots on June 3, 9, 13, 21, 22, 25; July 2, 6, 12, 14, 19, 23, 26, 30; August 5, 6, 13, 16, 20, 23, 27, 30. On these same dates, cool waves invariably made their appearance over the Pacific Slope, as appears both from the monthly records of temperature even in the Santa Clara Valley, but much more so by referring to the weather map of those dates, when you will see a predominating high lording it somewhere over the Pacific Slope. Well, but what about the warm waves? We can aver that these have invariably inserted themselves between the cool waves preceding and following them according to the laws herein above men-

tioned. Back of the twenty-three successful cases of our enumeration, where a marvelous order prevails and no break intervenes, lie the like happenings of the previous months and the experiments of about five years before that. And we may add that even up to the present date no exception has as yet appeared.

Our contention, however, is only for the Pacific Slope in general. Not every warm or hot wave or the opposite that enters upon the coast is making itself felt at every single station throughout the length and breadth of the Pacific States. In that case by consulting the weather map, one can see at a glance that the wave has indeed entered and covers a vast amount of territory. Cases of this kind can be quoted on demand. On the whole, however, a disturbance up north and down south sends its messengers even to us here and then people do marvel. asking what's the matter with the weather? The answer is there is an abnormal high or low in the north or the south and we stand within the sphere of its mighty influence.

Let these remarks suffice to justify the scientific value of the study of solar physics in its bearings upon things meteorological here below. It has been found that the meteorology of the Sun runs hand in hand with the meteorology of the Earth —Cfr. Sir Norman Lockyer in North American Review, June 1901, pages 827 et seqq.—and because the Earth is a planet, there is no room left to doubt that the meteorology of the Sun likewise affects the meteorology of the other planets. But secondaries always react on their primaries. Hence there is an avenue open for thinking that the solar spots may, at least in some measure, have a planetary origin.

This may account for the wonderful and undeniable fact to which the writer can bear ample witness—a fact, too, which is based upon the physical basis of observations taken by the most competent men of our weather bureau—that distinguished planetologists have invariably offered the same dates as ourselves, who have depended on solar markings only, for the entrance of warm and cool waves on the Pacific Slope. (By the way, the Professor of Meteorology at Harvard is a planetologist and other distinguished men might be named.)

As to the Moon in particular, we have no special information to offer, unless it be that a long series of experiments conducted under the auspices of the Greenwich Observatory, England, and the Royal Observatory of Belgium, tends to show that it has an effect on the circulation of the atmos-

phere. Cfr. *Bulletin de la Société Belge d' Astronomie, Revue des Sciences d' observation, Astronomie, Météorologie, Géodésie et Physique du Globe* for the year 1907.

Santa Clara College Observatory,
Santa Clara, California.

P. S. Since the above was written, much corroboration evidence has been accumulating. Long-range forecasts based on solar spots have been verified, as it were to order. But much matter of detail remains to be explained and the objections of the "man from Kansas" to be answered—which will be attended to in our next article. J. S. R.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

Part II. (Continued.)

Specific Statements of Fundamental Concepts Concerning the Constitution of Matter.

For Popular Astronomy.

Some very significant facts, pointing directly to the primitive condition and fundamental nature of all matter, will now be adduced in this connection. Under the condition that the, very approximately, spherical mass of the Sun is the result of the compression, or contraction, of a vastly extended volume of nebulous matter which was, at the very beginning of the process, in equilibrium, as to density, pressure and temperature, with the luminiferous ether whence it has been derived, it is easy to find the radius of the spherical volume of the gaseous mass when it began to differentiate from the ether, and to contract toward the present dimensions of the Sun. If we designate the present semidiameter of the solar globe by s, its mean density by D_s and the density of the ether by D_e, and reduce the former density to the latter by assuming the present volume of the Sun to be sufficiently expanded, it is obvious that the maximum radius (R_s) of the expanded spherical volumes in terms of the radius of the solar globe at the present time, will be given by the equation $R_s = s.\sqrt[3]{\frac{D_s}{D_e}}$; (a) and if the

present mean distance of the Earth from the Sun be denoted by S, the maximum radius (R_n) of the primitive spherical nebula, in terms of the Earth's mean distance which is taken as unity, is expressed by the equation; $R_n = \frac{s}{S} \cdot \sqrt[3]{\frac{D_s}{D_e}}$; (b).

The mean distance (S), corresponding to the solar parallax of very nearly 8.″80, is 92,891,300 miles, and the present mean radius of the Sun, for the *apparent* semidiameter 15′: 59″.63, is 432,175 miles, while the mean density (D_s) of the solar mass 1.414 times that of the water standard, or unit. From the observed value of the "solar constant," or measure of the thermal radiation from the Sun, and from the photometrically determined intensity of the luminous radiation from unit surface of the solar disk, I have found by means of two algebraic expressions for the "law of radiation" in each case, analytically derived,—in a manner to be subsequently set forth—from the fundamental concepts of my "astronomical theory of the molecule," that the density of the luminiferous ether, relative to the normal density of atmospheric air, is $\frac{1}{19{,}263{,}000{,}000{,}000{,}000}$, and since the density, or weight per unit volume, of water is 773.4 times that of air, that the density (D_e) of the ether, relative to the normal density of water, is $\frac{1}{14{,}898{,}000{,}000{,}000{,}000{,}000}$ which, as numerical quantities of such magnitude are more conveniently expressed in powers of 10, may be written $\frac{1}{14898 \times 10^{15}}$ or as a decimal fraction, 6712×10^{-23}, and the same value for the density I have found by means of two other independent methods, based upon my theory, which furnish checks upon the accuracy of the determination above set forth. Substituting this value of D_e, together with those of s and D_s above given in equation (a), the value of the maximum radius (R_s) of the primitive solar nebula—considered as a sphere—is found to be 2,761,920 times the semidiameter of the Sun, and therefore 1,193,632,776,000 miles, while, if all the aforesaid known values be introduced into the right-hand member of equation (b), the maximum radius (R_n) referred to the mean-distance of the Earth from the Sun as the unit, is found to be 12,850, a value about 10 per cent greater than that stated in the preceding part of this paper, and which was taken from a preliminary, or provis-

ional, computation, while the result just given has been derived from a more correct and exact value of the relative density of the ether.

The absolute temperature (T_e) of the luminiferous ether is determinable from the density (D) thereof, relative to that of atmospheric air under the normal conditions, through the following equation of my theory; $T_e = T_a . D^{\frac{2}{3}}$; (c) in which T_a represents the normal absolute temperature of atmospheric air, freed from the augmentation due to the solar thermal radiation which raises the atmospheric temperature, materially, only in the lower strata, while not affecting the temperature of the ether beyond. Thus taking the temperature of the "freezing-point" of water, or 32 degrees Fahrenheit, as the standard, we have $32° + 459.°65 = 491.°65$ as the corresponding absolute temperature, and deducting therefrom 112.87 degrees which I have found to represent, well, the augmentation due to solar heat, there results, as the value of T_a in this case, 378.78 degrees, or 80.87 degrees below the zero of the Fahrenheit scale, and this is, very nearly, the lowest terrestrial atmospheric temperature ever observed near the Siberian "magnetic pole"—a very significant fact, as will be subsequently shown. Substituting this value of T_a, together with that of $D^{\frac{2}{3}}$, in equation (c), the absolute temperature of the ether is found to be $0.°000000005271$, or only a little more than the two-hundred-millionth part of a degree (Fahrenheit) above absolute zero, and thus we have both the temperature and the density of the ether, which are also the temperature and density of the matter of the incipient solar nebula at the time of its differentiation, or derivation, from that fundamental, superlatively tenuous and extremely cold, substance.

The absolute temperature (T_s) generated by the compression of this vastly extended, gaseous mass, down to the present dimensions of the Sun, is determinable through the following equations of my theory: $T_s = T_e R_s^2 = T_e . \left(\frac{R_n S}{s}\right)^2$; (d), the resulting value of T_s being 40,200 degrees Fahrenheit *absolute*. This temperature has been derived under the condition that the whole compression of the gaseous matter of the nebula has been *adiabatic* or in other words, that no heat has been gained by the mass, from sources other than compression, and that none has been lost therefrom, but, in order that there should be any compression under the

action of the force of gravity inherent in such a gaseous mass, there must have been loss by radiation from the surface thereof, otherwise, since the force of gravity at the surface varies inversely as the square of the mean radius of the contracting volume of the nebula while the generation of heat by the process of compression, and the consequent development, thereby, of a force directly antagonistic to that of gravity, as has been pointed out on a preceding page, varies also inversely as the square of said radius, the process of compression could not be carried on—or even have its inception—unless there were a loss of heat from the gaseous mass.

By a differentiation of that equation of my theory, connecting temperature and density in such a mass, I have found that in the process of compression from the original volume to the present dimensions of the Sun, two-thirds of the heat that would have been generated by *adiabatic* compression—were such possible—must have been radiated into space, and one-third retained in the contracted mass, this third part being the measure of the present maximum *internal* temperature of the Sun, which is to be found at a comparatively short distance below the apparent surface of the solar globe, at a depth of probably not more than 5000 miles, or just below the roots of the brilliant filaments constituting the highly luminous portions of the photosphere, and prominently visible in the penumbra of a sun-spot. The temperature due to *adiabatic* compression being, as above stated in round numbers, 40,200 degrees it follows that the present maximum absolute temperature of the internal matter of the Sun is 13,400 degrees. Furthermore, what may be called the "surface temperature" of the Sun, or, since that body does not possess a real, geometric surface (its superficial matter consisting of gases and vapors of varying densities) that of a mean level, or "interface," between the depth at which the internal temperature is a maximum, and the cold ether outside the solar globe, being the arithmetical mean between the absolute temperature of the ether, which is so small that it may be regarded as zero in this connection, and the maximum internal temperature aforesaid, is one-half the latter, or 6700 degrees, a value substantially the same as that derived by means of the several independent methods referred to in the preceding part of this paper. The results above stated in this connection are summarized as follows:

TABLE I

The Ether and the Incipient Solar Nebula	R_s	R_0	Absolute Temperature	Density
	2,761,920	12,850	0.°000000005271	6712×10^{-23} (water)
				5191×10^{-20} (air)
The Sun	1	0.004652	13,400° (Internal)	1.414 (water)
			6,700° (Surface)	1094.6 (air)

In the first column of Table I is set forth the maximum radius of the incipient solar nebula, in terms of the present semidiameter of the Sun, which is also set forth therein as 1, and in the second column are these quantities referred to the Earth's mean-distance as the unit.

In the third column are given the initial absolute temperature of the nebula (which is also that of the luminiferous ether) and the absolute temperature of the nebulous mass after its condensation into what we call the Sun—both the internal and the surface, or effective radiating temperature of that body being given—while the last column contains the relative density with respect to both the water unit and the normal density of atmospheric air, the density relative to air being that found, directly, from observational data, through the several methods and equations of my theory (which regards the ether as being, fundamentally, of the same nature and constitution as that of the atmospheric, and other, gases) the value of the density relative to the water standard being found simply by dividing the densities relative to air by the constant number 773.4.

Furthermore, it should be remarked that this density does not, necessarily, represent *mass*, or *weight*, per unit volume, but only the *volume* of each hollow, spherical shell, or molecule, of the ether, relative to the normal volume of the standard molecule of atmospheric air, this volume being inversely proportional to the density the expression whereof, in this case, is $D = \frac{1}{V}$ instead of $D = \frac{M}{V}$, the mass (M) being, in this connection, considered as unity for both substances, the volume (V), only being variable.

If the radiation of heat from the contracting nebula, and its generation by reason of the compression due to the nebular force of gravity, were to proceed *pari-passu*, the process of contraction would go on uniformly, but such is not the case, the heat being developed at a rate greater than that of radiation, so that, as has been stated, there results an

accumulation of thermal energy which, at certain definite—and definable—intervals, overcomes the compressive force of gravity and by reason of this fact, combined with the effect of centrifugal force due to the rotation of the nebula, superficial portions of the matter of the tenuous gaseous mass are severed therefrom, and left behind in the process of contraction.

From the relation between density and temperature, as expressed by certain equations of my theory, I have found that whenever the absolute temperature is increased three times by the compression, the force of gravity at the surface is thus overcome, and fission occurs.

The relation between the temperature (T) generated by the compression, and the radius (R_n) of the contracting sphere, is expressed by the equation: $T_n = \frac{1}{R_n^2}$; whence, $R_n = \sqrt{\frac{1}{T_n}}$, the temperature denoted by T_n being a proportional quantity, in this case, the value whereof is 3, so that, beginning with the maximum value of R_n, which is 12,850, and dividing this by $\sqrt{3}$ we obtain 7,420 as the mean radius at which the temperature of the mass will be tripled and fission result, and by continuing this process downward until the present surface of the Sun is reached at the relative radius $R_n = 0.004652$, we obtain a series of intervals at which, roughly annular, portions of the superficial matter of the nebula are detached, and also the mean absolute temperature and density of the matter of these severed portions whence the planets and comets have been, subsequently, formed. The following table contains, in the first column, the values of n, or the number of intervals, counting from the outermost, downward, in the second column the values of the radius (R_n) of the contracted sphere at the numbered interval; in the third column, the corresponding absolute temperatures, and in the fourth, the density relative to that of the water unit.

The temperature corresponding to $n = 1$ in this table, is that of the luminiferous ether, and three times this value would be the temperature of the matter separated at the radius 7,420, corresponding to $n = 2$, but under the condition that two-thirds of the heat generated has been radiated into space during the interval, and one-third retained in the nebulous mass, the *actual* temperature at $n = 2$, must have been the same as the fundamental temperature or that of the ether, as aforesaid, so that all the temperatures set forth

in the third column, below $n = 1$, are *actual* temperatures due to heat retained in the condensing mass, and by multiplying these by three, we obtain the absolute temperatures which would have been produced by the compression to each value of the mean radius of the nebula, had there been no loss by radiation–the compression being considered as *adiabatic*. As a matter of convenience, the densities, relative to the water unit, in the fourth column are expressed in terms of the powers of 10, down to, and including, $n = 11$, and thence, downward to the Sun they are written as decimal fractions in the ordinary way.

TABLE II

n	R_n	Absolute Temperature	Density	
1	12,850	0°.000000005271	6512×10^{-23}	The Ether
2	7,420	0°.000000005271	3488×10^{-22}	
3	4,284	0 .0000000158	1812×10^{-21}	
4	2,474	0 .0000000474	9417×10^{-21}	
5	1,428	0 .000000142	9893×10^{-20}	
6	824	0 .000000427	2543×10^{-19}	
7	476	0 .00000128	1321×10^{-18}	
8	275	0 .00000384	6865×10^{-17}	
9	159	0 .0000115	3567×10^{-16}	
10	92	0 .0000345	1832×10^{-15}	
11	53	0 .000104	9631×10^{-15}	
12	31.00	0 .000312	0.0000000000050	Orbit of Neptune
13	18.00	0 .000936	0.0000000000260	" " Uranus
14	10.00	0 .00281	0.000000000135	" " Saturn
15	5.89	0 .00842	0.000000000702	" " Jupiter
16	3.39	0 .0252	0.00000000360	" " Asteroids
17	1.96	0 .0756	0.0000000190	" " Mars
18	1.13	0 .227	0.0000000985	" " Earth
19	0.65	0 681	0.000000512	" " Venus
20	0.38	2 .043	0.00000266	" " Mercury
21	0.2171	6°.128	0.0000138	
22	0.1256	18 .38	0.0000718	
23	0.0725	55 .14	0.000373	
24	0.0418	165 .42	0.00194	
25	0.0241	496 .3	0.0100	
26	0.0140	1,488 .9	0.0524	
27	0.0081	4,466 .7	0.272	
28	0.004652	13,400 .1	1.414	The Sun

The process of development of the Sun, from the primitive nebula, is clearly indicated in Table II, and if this nebula were drawn from the numerical data thus tabulated, the ideal depiction would be an almost perfect similitude of the great nebula in Andromeda.

In the determination of these tabulated values, the nebula has been considered as a sphere, but further evidence, from both theory and observation, will be presently introduced

to show that it must have been of a roughly oval shape, with its longest diameter between three and four times the shortest.

It will be shown also that the rings, or belts, of separated matter were of great width, as were also the spaces, comparatively devoid of nebulous matter, between them; these void spaces constituting the dark rifts, or "lanes," such as those in the great nebula in Andromeda, to which attention was first called by Professor G. P. Bond, of the Harvard College Observatory—of which he was director, about the middle of the last century—these rifts, so observed, being two in number and known as "Bonds dark lanes" from their discoverer.

The process of derivation of the members of the solar system—the planets with their satellites, and the comets as well—the nuclei whereof were formed by secondary and tertiary condensations in the matter cast off from the primary solar nebula, in the manner above described, can be traced by means of the same analytical method, based upon the principles of my theory, that I have employed in the case of the derivation of the Sun from the primitive nebulous mass.

Designating the relative density of any planetary body by D_p, and that of the separated matter in, and from, which it has condensed by reason of compression due to its intrinsic force of gravity, down to its present dimensions and density, by D_n, the initial radius (R_p) of the planetary nebulous matter, at the time of beginning of this secondary process of condensation, is determinable through the equation: $R_p = \sqrt[3]{\frac{D_p}{D_n}}$; ($d_1$) in terms of the mean radius of the planet at the present time, this radius being taken as 1—and from the equation: $T_p = \frac{T_n}{3}$. R_p: (e_1) the maximum absolute temperature of the mass, at the time of its formation into an approximately solid body, can be found, T_p, representing also the maximum internal absolute temperature of any planet, at the present time. In these equations, T_n which represents the absolute temperature of the gaseous matter in any belt or ring, at the time of beginning of the planetary condensation, is to be taken directly from the third column of Table II, and the density D_n of this matter from the fourth column thereof, while D_p represents the density—relative to the water-unit—of the planet at the time when

the compressed mass passed from the gaseous state into the *viscous* (it will be shown that the chemical constitution of the greatest part of the known matter of the Earth precludes the idea that, in the transition period from the gaseous to the solid state, it was *liquid* in the same sense as water is regarded; it indicates rather, that, at that time, the terrestrial matter, was in a condition similar to that of *molten glass*) after which the contraction due to loss of heat did not, of course, follow the thermodynamical laws governing the compression of gases.

In the case of the Earth, its mean density—relative to the water-unit—is known to be very approximately, 5.52, while that of the superficial strata, is only about one-half this, the greater density of the internal matter being due, principally, to the enormous pressure of the superincumbent strata of the so-called "crust," and therefore, the density (D_p) to be used in the equation (d_1) is 2.66, or that of the most abundant, superficial solid matter.

Substituting this value, and that of D_n taken from Table II, for $n = 18$, the initial radius (R_p) of what may be called the "terrestrial nebula," in its most expanded state, is found to be 300 times the mean radius of the terrestrial spheroid at the present time, or nearly 1,189,000 miles.

Squaring this value of R_p, and substituting the result, together with one-third the value of T_n (since, in the process of planetary compression, two-thirds of the heat that would result from *adiabatic* compression is radiated away just as in the case of the primitive solar nebula) taken from Table II, for $n = 18$, in equation (e_1), we obtain 6,800 degrees Fahrenheit as the maximum absolute temperature of the internal matter of the Earth, which is equivalent to 6,340 degrees when referred to the zero of the ordinary scale. Therefore, if we take the mean temperature of the whole surface of the Earth at forty degrees, the excess of temperature between the surface and the internal matter, is 6,300 degrees, so that, if the increase of temperature downward from the surface, be at an average rate of 55 feet per degree, Fahrenheit, which is the mean value derived from a number of the best determinations in the case of mines, wells and borings of great depth, and also the value, as found through an equation derived from my theory, in a manner to be subsequently shown, this equation being $p = \frac{k}{R}$, (*t*) (in which k

represents the mean conductivity of the the matter of the "crust", and R, the rate of radiation from the Earth's surface, or the quantity of heat radiated from unit surface, in unit time, the algebraic formula for which furnishes a crucial test of my theory) the maximum internal temperature is reached at a depth of 66 miles. This superficial "envelope"—as it may be regarded—the temperature whereof increases downward to the maximum, at the depth aforesaid, may be called the "crust" of the Earth although, as has been stated there is abundant reason for the statement that the whole mass of our globe is, substantially, a *solid* of great rigidity, notwithstanding the fact that it is exceedingly hot not very far below the surface. This temperature is, of course, far above that of the melting-points of the metals and of many of the substances entering into the composition of the Earth, but it is *barely* the temperature of the melting point of the element "carbon" and its chemical congener "silicon", under the ordinary conditions of *pressure*, and it is very obvious that, under the enormous pressure of the 66 miles of depth of the "crust" aforesaid, even these two, most highly refractory, substances must be in the *solid* state and, under this condition, would constitute a very rigid mass such as that which is, evidently, the nucleus of our globe which is practically of the same density and temperature throughout its whole extent below the comparatively thin "crust" the depth whereof is 66 miles or only the one-sixtieth part of the present mean semidiameter of the Earth.

The aforesaid thickness of the so-called "crust" is only a *mean* value dependent upon the *mean* thermal conductivity of the matter of the crust, so that in some regions this crust may be considerably thicker than the average of 66 miles, and in others thinner; moreover, the surface matter of the Earth is never at absolute rest but is always yielding, more or less, to divers stresses brought to bear upon it by extraneous forces traceable ultimately to the action of the Sun and having a rough periodicity, as will be demonstrated, and the kinetic energy due to even very minute movements of the matter of the crust at a depth of only a few miles, as in the case of the more violent movements known as "earthquakes" (the seismic foci being generally located at depths of from three to five miles, although in some cases the focus has been found at a depth of thirty miles below the surface) may generate, in portions of the distributed strata triturated by the movement,

heat, to a degree quite as great, or even greater, than the maximum internal temperature at the lower depth aforesaid, and to this superficial, and local, action, according to my hypothesis, is to be attributed seismic phenomena, the earthquakes and volcanoes. In this view, the maximum internal heat of our globe, generated by the original gaseous compression, is only a remote factor in the causation of said phenomena, the slow and uniform contraction of the Earth by reason of the secular cooling of its internal matter, resulting in the corrugation of the previously comparatively smooth surface into elevations and mountain ranges in proximity to correlated ocean depths, thereby producing axes of weakness, or "faults," in the rocky strata of later deposition, portions of these strata giving way at intervals, to the stresses put upon them by extraneous forces aforesaid, the amount of the development and the amplitude of the vibration, or "shock," caused thereby, being comparatively small but productive frequently, of violent swayings and disastrous results on the surface of the Earth by reason of the great velocity of the vibrations in the strata affected by the "earthquake waves." While we do not possess positive knowledge, derived from actual observation, as to the nature and condition of the terrestrial matter at considerable depths below the surface, we do know quite accurately, the relative proportions and chemical constitution of the superficial matter, and from this fact, in connection with spectroscopic evidence presented by the Sun, stars, gaseous nebulæ and comets, when viewed in the light of the nebular hypothesis as conceived by my theory, we can deduce conclusions in regard to the internal matter of our globe, which possess a degree of probability so great that they approach what may be rationally regarded as a very close approximation to positive knowledge in this respect, and more than this is not to be anticipated until some mechanical means of reaching the internal matter at the depth of 66 miles—by borings or otherwise,—can be devised and this, pre-requisite while, in the light of what has been accomplished in engineering achievements, it cannot be regarded as an absolute impossibility, is practically, a very remote contingency, in all probability.

The chemical element *silicon* in combination with the gas *oxygen*, in the form of the solid substance known as "silica" (of which pure quartz, rock crystal, sand and other minerals are specimens) the silicates of alumina, etc., constitute by

far the greater portion of the superficial matter of the Earth, the metals—even iron—abundant as they are, being inconsiderable in quantity when viewed in this connection, they constituting only about one-tenth, by weight, of the whole superficial matter, so far as known. At the time when the terrestrial matter was transformed from the gaseous into the *viscous* state, the temperature thereof was far above that at which oxygen could combine, chemically, with silicon to form the solid silica and the silicates aforesaid, and when said matter had cooled to a degree sufficient to permit this combination, the transformation was effected only upon, and to a small distance below, the surface of the crust, by reason of the fact that the internal temperature continued to be above that of "dissociation," and that the gas oxygen which is a light superficial element, incapable of penetrating to very great distances below the surface, could not reach and combine with the silicon at considerable depths. In view of these facts, it is most reasonable to conclude that, while the surface matter is thus chiefly composed of chemical combinations of silicon with oxygen and other elements, one substance, at least, in its elementary form enters into the constitution of the nucleus of the Earth, at an average depth of 66 miles and even into that of the crust at a considerably higher level, and that this is the element *silicon.*

One of the best attested of all the many important disclosures made by the spectroscope in the hands of skillful and eminent physicists, is that of the presence of carbon in some form—notably in that of a combination of carbon with the gas hydrogen as a hydro-carbon—in the Sun and many of the stars, comets and gaseous nebulæ, and it is also well-known that the principal part of the light radiated by the Sun is emitted from incandescent solid matter in a state of fine division, suspended in an atmosphere of highly heated, but much less luminous gases.—hydrogen etc.,—this light-giving portion of the solar globe being known as the "photosphere" the temperature whereof must be as high—or even higher—than the effective surface temperature of the Sun, which is 6,700 Fahrenheit (absolute) according to my determinations as stated on preceding pages, and the only *known* substance that can remain in the solid state at so high a temperature, is the element *carbon* and we might therefore expect to find this substance in abundance in the superficial matter of our globe, but aside from the carbon found in the

"coal-measures," and which is known to be of vegetable origin, there is only a comparatively small quantity of this element, in approximately pure condition, and known as "graphite", existing in the older geological rocks, but its absence from the superficial matter can be accounted for very easily. It is very evident, from what has been remarked above concerning the chemical combinations of silicon and oxygen aforesaid, that even had carbon existed in great quantity on, and just below the surface of the Earth, when the temperature had fallen sufficiently to allow chemical combination with oxygen to take place, the resultant could not have been a solid, or solids, as in the case of silicon and oxygen, but must have been invisible gases, ether in the form of carbon-dioxide, or carbonic-acid gas, the former gas, subsequently entering into the composition of plant and animal life, as one of the chief constituents thereof, and also combining with oxygen and calcium and like elementary matter to form the great system of rocks known as carbonates of lime etc., while the monoxide was occluded in the lower depth where the supply of oxygen was deficient.

A portion of the carbon thus coverted into vegetable matter was subsequently, deeply buried under earth and water, and slowly coverted into that combination of carbon with other matter, which is called "coal."

The pure primitive solid carbon must therefore have quite wholly disappeared from the superficial matter of the Earth at small depths, but the heavy hydro-carbon gases that are ejected from the craters of volcanoes in violent eruption, and which cover the volcanic mountain and the surrounding country with a heavy pall of black smoke when they have come into contact with the oxygen of the atmosphere and flashed into flame; the gaseous and liquid hydro-carbons that swell up so abundantly from the depths of the Earth in many regions and which have proved so useful to man in many ways, all bear testimony to prove the existence of abundant quantities of primitive carbon at considerable depths, and lead directly, and rationally to the conclusion that it, as well as its chemical congener silicon, is one of the chief constituents of the solid nucleus of our globe.

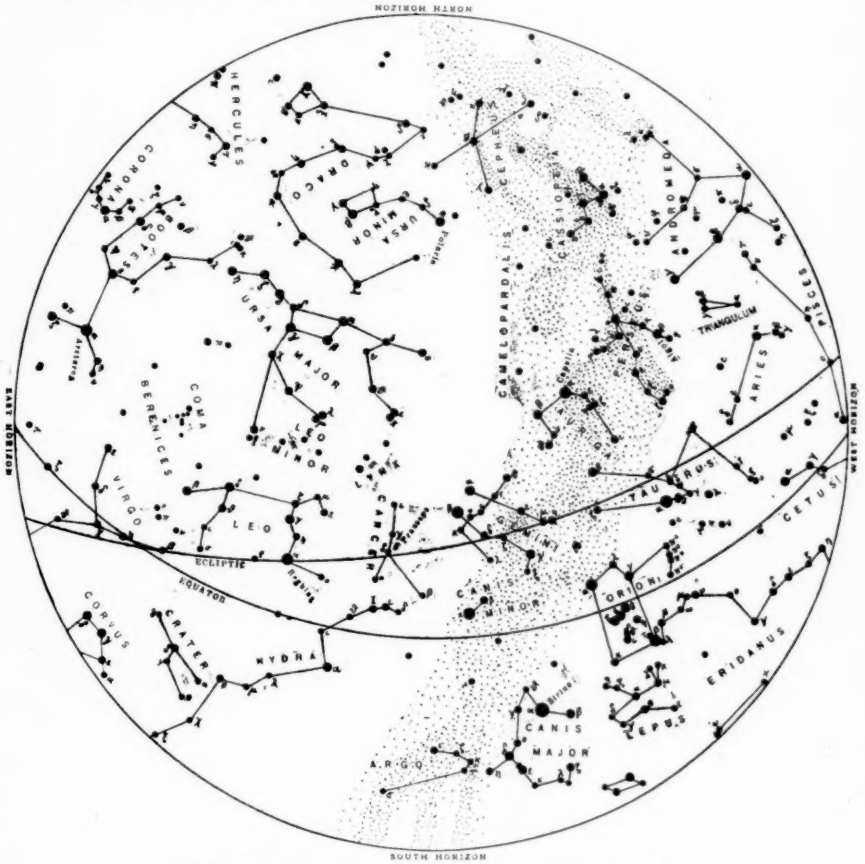
St. Paul, Minn.

To be continued.

PLANET NOTES FOR MARCH 1908.

H. C. WILSON.

Mercury is morning star and will be at greatest elongation, west from the Sun 27° 49′, on the morning of March 26. The planet at this time will be only half as bright as it is under the most favorable conditions. Mercury will be at aphelion March 28.



THE CONSTELLATIONS AT 9:00 P. M., MARCH 1, 1908.

Venus is evening star, very brilliant in the west soon after sunset. The planet will soon be visible to the naked eye in full sunlight in the afternoon to those who know just where to look for it. Venus will be at perihelion on March 31.

Mars having passed Saturn in January, is moving westward and northward away from the latter and during March will journey through Aries in-

to Taurus. The apparent diameter of the planet is now under 6″ so that the markings of its surface are not easily seen.

Jupiter is the brilliant planet seen nearly overhead in the early part of the night. The ruddy "belts" are easily seen with a small telescope and with a large instrument are full of fine details. The four bright satellites are seen at a glance with the smallest telescope. Their orbits this year are nearly in the plane with the Earth and so each one exhibits all the "phenomena," transit of the satellite, transit of the shadow, eclipse and occultation by the planet.

Saturn will be in conjunction with the Sun March 20 and so will not be in position for study this month.

Uranus may be found with a telescope in the morning but it is not in good position for study.

Neptune may be studied with a good telescope in the early evening, a little way west and north of the star ζ Geminorum. There has been quite a little discussion among some of the English students of astronomy as to whether Neptune is really easily distinguishable by its disk. With a large telescope and good seeing there is never any question about this. The disk of the planet is very plainly different from the spurious disk of a star of the same brightness.

Occultations visible at Washington.

Date 1908	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle f'm N. °	EMERSION. Washington M.T. h m	EMERSION. Angle f'm N °	Duration. h m
Mar. 7	Mayer 121	6.4	6 10	44	7 25	275	1 15
10	η Geminorum	3.5	6 26	25	7 16	320	0 50
11	44 Geminorum	5.9	4 54	46	6 01	303	1 07
11	δ Geminorum	3.5	14 9	117	15 02	262	0 53
19	*n* Virginis	6.5	16 50	109	18 02	303	1 12
22	B.A.C. 5408	6.4	11 35	73	12 24	335	0 49

Phenomena of Jupiter's Satellites.

Central Standard Time, reckoning from noon.

	h	m			
Mar. 1	5	42	IV	Ec.	Dis.
	6	48	III	Oc.	Dis.
	9	41	I	Oc.	Dis.
	10	25	IV	Ec.	Re.
	12	44	I	Ec.	Re
	13	28	III	Ec.	Re.
2	7	00	I	Tr.	In.
	7	46	I	Sh.	In.
	9	20	I	Tr.	Eg.
	10	06	I	Sh.	Eg.
3	7	13	I	Ec	Re.
5	12	18	II	Oc.	Dis.
7	6	26	II	Tr.	In.
	8	11	II	Sh.	In
	9	23	II	Tr.	Eg.
	11	07	II	Sh.	Eg.
	14	20	I	Tr.	In.
	15	12	I	Sh.	In.
8	10	16	III	Oc.	Dis.
	11	28	I	Oc.	Dis.
	14	39	I	Ec.	Re.

	h	m			
Mar. 9	5	43	IV	Tr.	In.
	6	07	II	Ec.	Re.
	8	47	I	Tr.	In.
	9	40	I	Sh.	In.
	10	31	IV	Tr.	Eg.
	11	07	I	Tr.	Eg.
	12	00	I	Sh.	Eg
	15	02	IV	Sh.	In.
10	5	55	I	Oc.	Dis.
	9	03	I	Ec.	Re.
11	6	29	I	Sh.	Eg.
12	7	42	III	Sh.	Eg.
	14	39	II	Oc.	Dis.
14	8	49	II	Tr.	In.
	10	48	II	Sh.	In.
	11	45	II	Tr.	Eg.
	13	44	II	Sh.	Eg.
15	13	16	I	Oc.	Dis.
	13	48	III	Oc.	Dis.
16	8	42	II	Ec.	Re.
	10	35	I	Tr.	In.

	h	m					h	m			
Mar.16	11	35	I	Sh.	In.	Mar.23	13	30	I	Sh.	In.
	12	55	I	Tr.	Eg.		14	44	I	Tr.	Eg.
	13	55	I	Sh.	Eg.	24	9	33	I	Oc.	Dis.
17	7	44	I	Oc.	Dis.		12	58	I	Ec.	Re.
	11	03	I	Ec	Re.	25	6	52	II	Tr.	In.
	13	55	IV	Oc.	Dis.		7	58	I	Sh.	In.
18	6	4	I	Sh.	In.		9	12	I	Tr.	Eg.
	7	22	I	Tr.	Eg.		10	19	I	Sh.	Eg.
	8	24	I	Sh.	Eg.	26	7	24	III	Tr.	In.
19	7	27	III	Tr.	Eg.		7	27	I	Ec.	Re.
	7	59	III	Sh.	In.		8	03	IV	Sh.	In.
	11	41	III	Sh.	Eg.		11	06	III	Tr.	Eg.
21	11	14	II	Tr.	In.		11	58	III	Sh.	In
	13	25	II	Sh.	In.		12	55	IV	Sh.	Eg.
	14	10	II	Tr.	Eg.	28	13	41	II	Tr.	In.
23	6	14	II	Oc.	Dis.	30	8	40	I	Oc.	Dis.
	11	17	II	Ec	Re.	31	11	24	II	Oc.	Dis.
	12	24	I	Tr.	In.						

Note.—In., denotes ingress; Eg., denotes egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., Transit of the Satellite: Sh., transit of the shadow.

COMET NOTES.

Encke's Comet Rediscovered.—A cablegram received at Harvard College Observatory January 3, from Kiel, Germany, states that Encke's comet was photographed by Professor Max Wolf on January 2. Its position was

Jan. 2.2358 Gr. M. T. R. A. $23^h\ 03^m\ 16^s$ Decl. $+1^\circ\ 19'$.

This indicates that the ephemeris, calculated from the elements given below, required a correction of about $+3^m$ in R. A. and $-15'$ in Decl. The comet is visible in a large telescope.

Elements and Ephemeris of Encke's Comet for 1908.—In *A.N.* 4222 are given elements of this periodic comet, computed for the epoch 1908.0 by Mr. M. Kamensky and Miss E. Korolikov. They are taken from the *Bulletin de l'Acad. Imp. des Sciences de St Pétersbourg.* 1907.

ELEMENTS.

Epoch and Occultation Feb. 22.0 (Berlin.)

$$\left.\begin{aligned} \pi &= 159\ 05\ 39.00 \\ \Omega &= 334\ 30\ 17.77 \\ i &= 12\ 36\ 40.54 \end{aligned}\right\} \ 1908.8$$

$\phi = 57\ 56\ 57.17 - 2.''394\,\tau$ $\qquad \tau = \dfrac{t - t_0}{1200}$

$\mu = 1076.''45733 + 0.''067715\,\tau$

T = 1908 April 30.1913 (Berlin)

Ephemeris of Encke's Comet.

Berlin 0^h	α			δ		log r	log Δ	Aberration Time.	
1908	h	m	s	°	′			m	s
Feb. 4	23	38	07	+ 5	07.5	0.2130	0.3435	18	19
8		44	04	5	43.1	1992	3408		12
12		50	20	6	21.0	1846	3373	18	04
16	23	56	55	7	01.1	1692	3329	17	55
20	0	03	51	7	43.7	1528	3278		42
24		11	09	8	28.3	1354	3219		28
28		18	51	9	15.3	1168	3151		11

Berlin 0^h	α			δ			log r	log Δ	Aberration Time.	
	h	m	s	°	′				m	s
1908										
Mar. 1	0	22	53	+ 9	39.6		0.1069	0.3113	17	01
3		27	00	10	04.5		0967	3074	16	52
5		31	14	10	30.0		0861	3031		41
7		35	35	10	56.1		0752	2985		31
9		40	06	11	22.6		0638	2938		20
11		44	43	11	49.6		0520	2888	16	09
13		49	27	12	17.3		0396	2834	15	57
15		54	24	12	45.7		0267	2776		45
17	0	59	29	13	14.5		0.0133	2716		31
19	1	04	44	13	43.7		9.9992	2652		18
21		10	10	14	13.4		9843	2586	15	4
23		15	49	14	43.5		9689	2515	14	50
25		21	40	15	13.9		9526	2440		34
27		27	44	15	44.7		9355	2360		19
29		34	02	16	15.7		9175	2276	14	02
31	1	40	36	+ 16	46.7		9.8984	0.2186	13	45

VARIABLE STARS.

Approximate Magnitudes of Variable Stars on Jan. 1, 1908.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900.		Decl. 1900.		Magn.	Name.	R. A 1900		Decl. 1900		Magn.
	h	m	°	′			h	m	°	′	
X Androm.	0	10.8	+46	27	13.3*d*	R Persei	3	23 7	+35	20	13.4*d*
T Androm.		17.2	+26	26	10.0 *i*	Nov. Per. 2		24.4	+43	34	13.3*d*
T Cassiop.		17.8	+55	14	10.0*d*	S Fornacis		41.9	−24	42	8.5
R Androm.		18.8	+38	1	13.2*d*	T Tauri	4	16.2	+19	18	10.4
S Ceti		19.0	− 9	53	9.7 *i*	R Tauri		22.8	+ 9	56	<13
Y Cephei		31.3	+79	48	13.0*d*	W Tauri		22.2	+15	49	8.4 *i*
U Cassiop.		40.8	+47	43	13.5 *i*	S Tauri		23.7	+ 9	44	<12
RW Androm.		41.9	+32	8	13.3	T Camelop.		30.4	+65	57	8.8 *i*
V Androm.		44.6	+35	6	12.2 *i*	RX Tauri		32.8	+ 8	9	<13
RR Androm.		45.9	+33	50	<13.5	X Camelop.		32.6	+74	56	9.0 *i*
W Cassiop.		49.0	+58	1	10.6*d*	V Tauri		46.2	+17	22	12.0 *i*
RX Androm.		58.9	+40	46	13.0	R Orionis		53.6	+ 7	59	9.8*d*
U Androm.	1	9.8	+40	11	<13.5	R Leporis		55.0	−14	57	10.0
S Piscium		12.4	+ 8	24	11.0 *i*	V Orionis	5	0.8	+ 3	54	9.7*d*
S Cassiop.		12.3	+72	5	13.2 *i*	T Leporis		0.6	−22	2	10.2
U Piscium		17.7	+12	21	11.8	R Aurigae		9.2	+53	28	9.2*d*
R Piscium		25.5	+ 2	22	14 *d*	S Aurigae		20.5	+34	4	11.0
RU Androm.		32.8	+38	10	10.0*d*	W Aurigae		20.1	+36	49	10.0
Y Androm.		33.7	+38	50	9.0*d*	S Orionis		24.1	− 4	46	10.5*d*
X Cassiop.		49.8	+58	46	10.0	T Orionis		30.9	− 5	32	10.0
U Persei		53.0	+54	20	9.0 *i*	S Camelop.		30.2	+68	45	11.0*d*
S Arietis		59.3	+12	3	11.5 *i*	RR Tauri		33.3	+26	19	12.0
R Arietis	2	10.4	+24	35	8.4 *i*	U Aurigae		35.6	+31	59	10.0*d*
W Androm.		11.2	+43	50	13.8*d*	U Orionis		49.9	+20	10	12.0
Z Cephei		12.8	+81	13	13.5*d*	V Camelop.		49.4	+74	30	<13.5
o Ceti		14.3	− 3	26	5.2*d*	Z Aurigæ		53.6	+54	18	9.0
S Persei		15.7	+58	8	8.6 *i*	X Aurigae	6	4.4	+50	15	10.6*d*
R Ceti		20.9	− 0	38	13.5*d*	V Aurigae		16.5	+47	45	12.6
U Ceti		28.9	−13	35	10.0 *i*	V Monoc.		17.7	− 2	9	9.7*d*
RR Cephei		30.4	+80	42	13.6*d*	R Monoc.		33.7	+ 8	49	13.0
R Trianguli		31.0	+33	50	10 0 *i*	S Lyncis		35.9	+58	0	13.5*d*
T Arietis		42.8	+17	6	8.8	W Monoc.		47 5	− 7	2	10.4*d*
W Persei		43.2	+56	34	10.0*d*	Y Monoc.		51.3	+11	22	13.2*d*
U Arietis	3	5.5	+14	25	8.4 *i*	X Monoc.		52.4	− 8	56	8.4*d*
X Ceti		14.3	− 1	26	13.4*d*	R Lyncis		53.0	+55	28	9.3*d*
Y Persei		20.9	+43	50	10.0*d*	V Can. Min.	7	1.5	+ 9	2	12.8*d*

Approximate Magnitudes of Variable Stars on Jan. 1, 1908—Con.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn.
R Gemin.	6	1.3	+22	52	12.0*d*	U Cygni	20	16.5	+47	35	8.0 *i*
R Can. Min.		3.2	+10	11	9.6 *i*	RW Cygni		25.2	+39	39	8.6*d*
RR Monoc.		12.4	− 1	17	10.6*d*	Z Delphini		28.1	+17	7	8.5 *i*
V Gemin.		17.6	+13	17	9.0 *i*	ST Cygni		29.9	+54	38	13.2*d*
S Can Min.		27.3	+ 8	32	11.8*d*	Y Delphini		36.9	+11	31	10.8*d*
T Can. Min.		28.4	+11	58	11.0*d*	S Delphini		38.5	+16	44	10.8*d*
U Can. Min.		35.9	+ 8	37	13.5*d*	V Cygni		38.1	+47	47	11.6*d*
S Gemin.		37.0	+23	41	<13.5	Y Aquarii		39.2	− 5	12	10.4*d*
T Gemin.		43.3	+23	59	9.0 *i*	U Capricorni		42.6	−15	9	<13.5
U Puppis		56.1	−12	34	11.4	T Delphini		40.7	−16	2	13.5 *i*
R Cancri	8	11.0	+12	2	9.4*d*	W Aquarii		41.2	− 4	27	<13.5
V Cancri		16.0	+17	36	8.0 *i*	V Delphini		43.2	+18	58	<13.8
U Cancri		30.0	+19	14	12.0	T Aquarii		44.7	− 5	31	8.0*d*
X Urs. Maj.		33.7	+50	30	<12	RZ Cygni		48.5	+46	59	11.7 *i*
S Hydrae		48.4	+ 3	27	11.4 *i*	X Delphini		50.3	+17	16	13.0
W Cancri	9	4.0	+25	39	10.8	— Delphini		50.3	+17	20	9.5
Y Draconis		31.1	+78	18	13.5	R Vulpeculae		59.9	+23	26	8.6 *i*
R Leo. Min.		39.6	+34	58	8.3 *i*	X Cephei	21	3.6	+82	40	<13.5
R Leonis		42.2	+11	54	7.0 *i*	RS Aquarii		5.8	− 4	27	11.6*d*
V Leonis		54.5	+21	44	<1.15	Z Capricorni		5.0	−16	35	13.6*d*
R Urs. Maj.	10	37.6	+69	18	9.9*d*	R Equulei		8.4	+12	23	8.4 *i*
T Urs. Maj.	12	31.8	+60	2	7.0 *i*	T Cephei		8.2	+68	5	10.0*d*
RS Urs. Maj.		34.4	+59	2	12.0 *i*	RR Aquarii		9.8	− 3	19	<13
S Urs. Maj.		39.6	+61	38	8.6 *i*	X Pegasi		16.3	+14	2	9.8*d*
T Urs. Min.	13	32.6	+73	56	9.0*d*	T Capricorni		16.5	−15	35	10.4 *i*
R Can. Ven.		44.6	+40	2	8.0*d*	Y Capricorni		28.9	−14	25	<13.5
U Urs. Min.	14	15.1	+67	15	10.0*d*	S Cephei		36.5	+78	10	9.2*d*
S Bootis		19.5	+54	16	13.0 *i*	RU Cygni		37.3	+53	52	9.0
R Camelop.		25.1	+84	17	12.0 *i*	RR Pegasi		40.0	+24	33	12.2*d*
S Urs. Min.	15	33.4	+78	58	11.2*d*	V Pegasi		56.0	+ 5	38	10.0*d*
RR Herculis	16	1.5	+50	46	8.0	U Aquarii		57.9	+17	6	13.4*d*
W Herculis		31.7	+37	32	7.6 *i*	RT Pegasi		59.8	+34	38	13.4*d*
R Draconis		32.4	+66	58	12.6	T Pegasi	22	4.0	+12	3	13.5*d*
V Draconis	17	56.3	+54	53	<13.5	Y Pegasi		6.8	+13	52	<12
T Herculis	18	5.3	+31	0	9.0*d*	RS Pegasi		7.4	+14	4	9.0 *i*
W Draconis		5.4	+65	56	12.0 *i*	X Aquarii		13.2	−21	24	<13.5
X Draconis		6.8	+66	8	11.6*d*	RT Aquarii		17.7	−22	34	10.4 *i*
W Lyrae		11.5	+36	38	8.5	RV Pegasi		21.0	+29	58	12.0*d*
SV Herculis		22.3	+24	58	8.5 *i*	S Lacertae		24.6	+39	48	11.4*d*
RY Lyrae		41.2	+34	34	9.0 *i*	R Lacertae		38.8	+41	51	13.0*d*
RW Lyrae		42.1	+43	32	13.6*d*	S Aquarii		51.8	−20	53	<13.2
Z Lyrae		56.0	+34	49	11.8*d*	RW Pegasi		59.2	+14	46	8.8 *i*
RX Lyrae		50.4	+32	42	<13.5	R Pegasi	23	1.6	+10	0	11.5*d*
U Draconis	19	9.9	+67	7	13.4	V Cassiop.		7.4	+59	8	12.0*d*
U Lyrae		16.6	+37	42	9.4*d*	W Pegasi		14.8	+25	44	8.0 *i*
R Cygni		34.1	+49	58	13.4*d*	S Pegasi		15.5	+ 8	22	13.4*d*
RT Cygni		40.8	+48	32	8.4d	Z Androm.		28.8	+48	16	11.0 *i*
TU Cygni		43.3	+48	49	<13	— Androm.		33.8	+35	13	10.0 *i*
χ Cygni		46.7	+32	40	12.0 *i*	R Aquarii		38.6	−15	50	9.5
Z Cygni		58.6	+49	46	9.0 *i*	Z Cassiop.		39.7	+56	2	<13.6
S Cygni	20	3.4	+57	42	12.0 *i*	RR Cassiop.		50.7	+53	8	<13.5
S Aquilae		7.0	+15	19	9.2 *i*	Z Aquarii		47.1	−16	24	8.6
RS Cygni		9.8	+38	28	7.8	V Ceti		52.8	− 9	31	10.2 *i*
R Delphini		10.1	+ 8	47	13.2*d*	Z Pegasi		55.0	+25	21	8.6 *i*
SX Cygni		11.6	+30	46	13.8*d*	W Ceti		57.0	−15	14	9.5*d*
WX Cygni		14.8	+37	8	10.6	Y Cassiop.		58.2	+55	7	<13.5
V Sagittae		15.8	+20	47	13.0 *i*	R Cassiop.		53.3	+50	50	10.0*d*

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Vassar College, Mt. Holyoke, Whitin and Harvard Observatories.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei

	d	h
Mar.	2	22
	5	10
	7	22
	10	10
	12	22
	15	9
	17	21
	20	9
	22	21
	25	9
	27	20
	30	8

Z Persei

	d	h
Mar.	1	12
	4	14
	7	15
	10	16
	13	18
	16	19
	19	21
	22	22
	25	23
	29	0

RY Persei

	d	h
Mar.	2	23
	9	19
	16	16
	23	13
	30	10

RZ Cassiop.

	d	h
Mar.	2	6
	3	11
	4	15
	5	20
	7	1
	8	5
	9	10
	10	15
	11	20
	13	0
	14	5
	15	10
	16	14
	17	19
	19	0
	20	4
	21	9
	22	14
	23	18
	24	23
	26	4
	27	8
	28	13
	29	18
	30	23

RX Cephei

	d	h
Mar.	27	5

Algol

	d	h
Mar.	2	12
	5	9
	8	6
	11	3
	14	0
	16	20
	19	17
	22	14
	25	11
	28	8
	31	4

RT Persei

	d	h
Mar.	1	16
	2	12
	3	8
	4	5
	5	1
	5	21
	6	18
	7	14
	8	11
	9	7
	10	3
	11	0
	11	20
	12	17
	13	13
	14	9
	15	6
	16	2
	16	22
	17	19
	18	15
	19	12
	20	8
	21	4
	22	1
	22	21
	23	18
	24	14
	25	10
	26	7
	27	3
	27	23
	28	20
	29	16
	30	13
	31	9

λ Tauri

	d	h
Mar.	3	11
	7	10
	11	9
	15	7
	19	6
	23	5
	27	4
	31	3

RW Tauri

	d	h
Mar.	3	4
	5	22
	8	17
	11	11
	14	6
	17	0
	19	19
	22	13
	25	8
	28	2
	30	20

RV Persei

	d	h
Mar.	2	22
	4	22
	6	21
	8	20
	10	20
	12	19
	14	18
	16	18
	18	17
	20	16
	22	16
	24	15
	26	15
	28	14
	30	13

RW Persei

	d	h
Mar.	9	21
	23	2

RS Cephei

	d	h
Mar.	8	21
	21	7

RW Geminorum

	d	h
Mar.	3	16
	6	13
	9	9
	12	6
	15	3
	18	0
	20	20
	23	17
	26	14
	29	11

RW Monoc.

	d	h
Mar.	1	22
	3	20
	5	17
	7	15
	9	13
	11	11
	13	8
	15	6
	17	4
	19	2
	21	0
	22	21

RW Monoc.

	d	h
Mar.	24	19
	26	17
	28	15
	30	12

RU Monoc.

	d	h
Mar.	1	14
	2	11
	3	9
	4	6
	5	4
	6	1
	6	23
	7	20
	8	18
	9	15
	10	13
	11	10
	12	8
	13	5
	14	3
	15	0
	15	22
	16	19
	17	17
	18	14
	19	12
	20	9
	21	7
	22	4
	23	2
	23	23
	24	21
	25	18
	26	16
	27	13
	28	11
	29	8
	30	6
	31	4

R Canis Maj.

	d	h
Mar.	1	14
	2	17
	3	20
	4	23
	6	3
	7	6
	8	9
	9	12
	10	16
	11	19
	12	22
	14	1
	15	5
	16	8
	17	11
	18	15
	19	18

R Canis Maj.

	d	h
Mar.	20	21
	22	0
	23	4
	24	7
	25	10
	26	13
	27	17
	28	20
	29	23
	31	2

Y Camelop.

	d	h
Mar.	1	3
	4	10
	7	18
	11	1
	14	8
	17	16
	20	23
	24	6
	27	14
	30	21

RR Puppis

	d	h
Mar.	4	7
	10	17
	17	3
	23	14
	30	0

V Puppis

	d	h
Mar.	1	21
	3	8
	4	19
	6	6
	7	17
	9	4
	10	15
	12	2
	13	13
	14	23
	16	10
	17	21
	19	8
	20	19
	22	6
	23	17
	25	4
	26	15
	28	2
	29	12
	30	23

X Carinæ

	d	h
Mar.	1	17
	2	19
	3	21
	4	23
	6	1
	7	3
	8	5

Continued.

X Carinæ

	d	h
Mar.	9	7
	10	9
	11	10
	12	12
	13	14
	14	16
	15	18
	16	20
	17	22
	19	0
	20	2
	21	4
	22	6
	23	8
	24	10
	25	12
	26	14
	27	16
	28	18
	29	20
	30	22

S Cancri

Mar.	5	11
	14	23
	24	11

S Velorum

Mar.	4	18
	10	16
	16	15
	22	13
	28	11

RR Velorum

Mar.	2	8
	4	5
	6	2
	7	22
	9	19
	11	15
	13	12
	15	8
	17	5
	19	1
	20	22
	22	18
	24	15
	26	11
	28	8
	30	4

SS Carinae

Mar.	1	10
	4	17
	8	1
	11	8
	14	15
	17	22
	21	6
	24	13
	27	20
	31	3

Z Draconis

	d	h
Mar.	2	3
	3	11
	4	20
	6	5
	7	13
	8	22
	10	6
	11	15
	12	23
	14	8
	15	17
	17	1
	18	10
	19	18
	23	3
	22	12
	23	20
	25	5
	26	13
	27	21
	29	6
	30	15

RZ Centauri

Mar.	1	20
	2	18
	3	17
	4	15
	5	14
	6	12
	7	11
	8	9
	9	8
	10	6
	11	5
	12	3
	13	2
	14	0
	14	23
	15	21
	16	20
	17	18
	18	17
	19	15
	20	14
	21	13
	22	11
	23	10
	24	8
	25	7
	26	5
	27	4
	28	2
	29	1
	29	23
	30	22
	31	20

SS Centauri

Mar.	3	3
	5	14
	8	1
	10	13
	13	0
	15	12
	17	23
	20	11
	22	22
	25	10
	27	21
	30	9

δ Libræ

Mar.	1	4
	3	11
	5	19
	8	3
	10	11
	12	19
	15	3
	17	11
	19	18
	22	2
	24	10
	26	18
	29	2
	31	10

U Coronæ

Mar.	3	14
	7	0
	10	11
	13	22
	17	9
	20	20
	24	7
	27	18
	31	4

R Aræ

Mar.	2	10
	6	20
	11	6
	15	16
	20	2
	28	23

U Ophiuchi

Mar.	1	19
	2	7
	3	3
	3	23
	4	19
	5	15
	6	11
	7	7
	8	3
	9	0
	9	20
	10	16
	11	12
	12	8
	13	4
	14	0
	14	21
	15	17
	16	13

U Ophiuchi

	d	h
Mar.	17	9
	18	5
	19	1
	19	21
	20	17
	21	14
	22	10
	23	6
	24	2
	24	22
	25	18
	26	14
	27	10
	28	7
	29	3
	30	19
	31	15

Z Herculis

Mar.	4	10
	8	10
	12	10
	16	10
	20	10
	24	9
	28	9

RS Sagittarii

Mar.	3	1
	5	11
	7	21
	10	7
	12	17
	15	3
	17	13
	19	23
	22	9
	24	19
	27	5
	29	15

V Serpentis

Mar.	3	9
	6	20
	10	5
	13	18
	10	5
	13	18
	17	5
	20	16
	24	3
	27	14
	31	0

RZ Draconis

Period $13^h.2$

Mar.	1	16
	2	19
	3	21
	4	23
	6	2
	7	4
	8	7
	9	9

RZ Draconis

	d	h
Mar.	10	12
	11	14
	12	17
	13	19
	14	21
	16	0
	17	2
	18	5
	19	7
	20	10
	21	12
	22	15
	23	17
	24	19
	25	22
	27	0
	28	3
	29	5
	30	8
	31	10

RX Herculis

Mar.	1	18
	2	15
	3	12
	4	10
	5	7
	6	4
	7	2
	8	20
	9	18
	10	15
	11	12
	12	10
	13	7
	14	5
	15	2
	15	23
	16	21
	17	18
	18	15
	19	13
	20	10
	21	7
	22	5
	23	2
	23	23
	24	21
	25	18
	26	15
	27	13
	28	10
	29	7
	30	5
	31	2
	31	23

SX Sagittarii

Mar.	1	8
	3	10
	5	12
	7	14

Continued.

SX Sagittarii

	d	h
Mar.	9	16
	11	18
	13	20
	15	21
	17	23
	20	1
	22	3
	24	5
	26	7
	28	8
	30	10

RR Draconis

	d	h
Mar.	2	10
	5	6
	8	2
	10	22
	13	17
	16	13
	19	9
	22	5
	25	1
	27	21
	30	17

U Scuti

	d	h
Mar.	1	18
	2	17
	3	16
	4	15
	5	14
	6	13
	7	12
	8	11
	9	10
	10	9

U Scuti

	d	h
Mar.	11	7
	12	6
	13	5
	14	4
	15	3
	16	2
	17	1
	18	0
	18	23
	19	22
	20	21
	21	20
	22	18
	23	17
	24	16
	25	15
	26	14
	27	13
	28	12
	29	11
	30	10
	31	9

RX Draconis

	d	h
Mar.	1	10
	3	7
	5	5
	7	2
	9	0
	10	21
	12	19
	14	16
	16	14
	18	11
	20	9
	22	6

RX Draconis

	d	h
Mar.	24	3
	26	1
	27	22
	29	20
	31	17

RV Lyræ

	d	h
Mar.	3	28
	7	8
	10	23
	14	13
	18	3
	21	18
	25	8
	28	23

U Sagittæ

	d	h
Mar.	1	15
	5	0
	8	9
	11	18
	15	3
	18	12
	21	21
	25	7
	28	16

SY Cygni

	d	h
Mar.	1	5
	7	6
	13	6
	19	6
	25	6
	31	6

WW Cygni

	d	h
Mar.	2	4
	5	12
	8	19
	12	3
	15	10
	18	18
	22	2
	25	9
	28	17

SW Cygni

	d	h
Mar.	5	9
	9	23
	14	13
	19	2
	23	16
	28	6

VW Cygni

	d	h
Mar.	8	10
	16	21
	25	7

UW Cygni

	d	h
Mar.	1	16
	5	3
	8	14
	12	1
	15	11
	18	22
	22	9
	25	20
	29	7

W Delphini

	d	h
Mar.	4	16
	9	12
	14	7

W Delphini

	d	h
Mar.	19	2
	23	22
	28	17

RR Delphini

	d	h
Mar.	3	6
	7	21
	12	11
	17	1
	21	16
	26	6
	30	21

VV Cygni

	d	h
Mar.	2	5
	3	16
	5	4
	6	15
	8	2
	9	14
	11	1
	12	13
	14	0
	15	12
	16	23
	18	11
	19	22
	21	9
	22	21
	25	8
	25	20
	27	7
	28	19
	30	6
	31	18

UZ Cygni

	d	h
Mar.	27	21

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop.

	d	h
	(−5	19)
Mar.	8	17
	23	12

RX Aurigæ

	d	h
	(−4	0)
Mar.	12	6
	23	21

Y Aurigæ

	d	h
	(−0	18)
Mar.	1	7
	5	4
	9	1
	12	21
	16	18
	20	15
	24	11
	28	8

T Monoc.

	d	h
	(−7	23)
Mar.	6	10
Apr.	2	10

W Geminorum

	d	h
	(−2	22)
Mar.	7	1
	14	23
	22	21
	30	19

ζ Geminorum

	d	h
	(−5	0)
Mar.	1	3
	11	7
	21	10
	31	14

RU Camelop.

	d	h
	(−9	12)
Mar.	19	21

RR Geminorum

Period 9.5h

	d	h
	(−0	2)
Mar.	2	4
	3	8
	4	13
	5	18
	6	22
	8	3
	9	8
	10	12
	11	17
	12	21
	14	2

RR Geminorum

	d	h
Mar.	15	7
	16	11
	17	16
	18	20
	20	1
	21	6
	22	10
	23	15
	24	19
	26	0
	27	5
	28	9
	29	14
	30	18
	31	23

V Carinæ

	d	h
	(−2	4)
Mar.	5	2
	11	19
	18	12
	25	4
	31	21

T Velorum

	d	h
	(−1	10)
Mar.	4	19
	9	10
	14	2
	18	17
	23	8
	28	0

W Carinæ

	d	h
	(−1	0)
Mar.	1	14

Continued.

W Carinæ

	d	h
Mar.	5	23
	10	8
	14	17
	19	2
	23	11
	27	20

S Muscæ

	(−3	11)
Mar.	2	13
	12	5
	21	20
	31	12

T Crucis

	(−2	2)
Mar.	2	23
	9	16
	16	10
	23	4
	29	21

R Crucis

	(−1	10)
Mar.	2	21
	8	17
	14	13
	20	9
	26	5

S Crucis

	(−1	12)
Mar.	4	0
	8	17
	13	9
	18	2
	22	18
	27	11

W Virginis

	(−8	5)
Mar.	9	11
	26	18

V Centauri

	(−1	11)
Mar.	2	6
	7	17
	13	5
	18	17
	24	5
	29	17

R Triang. Austr.

	(−1	0)
Mar.	3	8
	6	18
	10	3
	13	12
	16	22
	20	7
	23	16
	27	2
	30	11

S Triang. Austr.

	(−2	2)
Mar.	6	22
	13	6
	19	13
	25	21

S Normæ

	d	h
	(−4	10)
Mar.	2	23
	12	17
	22	11

RW Draconis.
Period 10.6h

	(−0	3)
Mar.	1	15
	2	12
	3	9
	4	7
	5	4
	6	1
	6	22
	7	20
	8	17
	9	14
	10	11
	11	9
	12	6
	13	3
	14	1
	14	22
	15	19
	16	16
	17	14
	18	11
	19	8
	20	5
	21	3
	22	0
	22	21
	23	18
	24	16
	25	13
	26	10
	27	7
	28	5
	29	2
	29	23
	30	21
	31	18

RV Scorpii

	(−1	10)
Mar.	1	14
	7	15
	13	17
	19	18
	25	20
	31	21

RV Ophiuchi
Minimum.

Mar.	4	21
	8	13
	12	6
	15	22
	19	15
	23	7
	27	0
	30	16

X Sagittarii

	(−2	22)
Mar.	5	23

X Sagittarii

	d	h
Mar.	12	23
	20	0
	27	0

Y Ophiuchi

	(−6	5)
Mar.	6	22
	24	1

W Sagittarii

	(−3	0)
Mar.	7	7
	14	21
	22	11
	30	1

Y Sagittarii

	(−2	2)
Mar.	2	20
	8	14
	14	9
	20	4
	25	22
	30	17

U Sagittarii

	(−2	23)
Mar.	3	0
	9	17
	16	11
	23	5
	29	23

β Lyræ

	(−3	2)
	(−3	7)
Mar.	6	8
	13	0
	19	4
	25	22

κ Pavonis

	(−1	7)
Mar.	1	9
	10	11
	19	13
	28	16

U Aquilæ

	(−2	4)
Mar.	7	22
	14	23
	22	0
	29	0

XZ Cygni
Period 11.2h

	(−0	4)
Mar.	1	18
	2	17
	3	15
	4	14
	5	12
	6	10
	7	9
	8	7
	9	6
	10	4
	11	2
	12	1
	12	23
	13	22

XZ Cygni

	d	h
Mar.	14	20
	15	18
	16	17
	18	14
	19	12
	20	10
	21	9
	22	7
	23	6
	24	4
	25	2
	26	1
	26	23
	27	22
	28	20
	29	18
	30	17
	31	15

U Vulpeculæ

	(−2	3)
Mar.	5	18
	13	18
	21	17
	29	17

SU Cygni

	(−1	7)
Mar.	1	7
	5	3
	9	0
	12	20
	16	16
	20	12
	24	9
	28	5

η Aquilæ

	(−2	6)
Mar.	5	8
	12	13
	19	17
	26	21

S Sagittæ

	(−3	10)
Mar.	2	18
	11	3
	19	12
	27	22

X Vulpeculæ

	(−2	1)
Mar.	6	13
	12	20
	19	4
	25	12
	31	19

X Cygni

	(−6	19)
Mar.	5	19
	22	4

T Vulpeculae

	(−1	10)
Mar.	5	10
	9	20
	14	17
	18	1

T Vulpeculae

	d	h
Mar.	23	3
	27	14

WZ Cygni
Minimum
Period 14h

Mar.	1	16
	2	20
	4	0
	5	4
	6	8
	7	12
	8	16
	9	20
	11	0
	12	4
	13	8
	14	12
	15	16
	16	20
	18	0
	19	4
	20	8
	21	12
	22	16
	23	21
	25	1
	26	5
	27	9
	28	13
	29	17
	30	21

RV Capricorni
Period 10.7h

Mar.	1	15
	2	13
	3	10
	4	8
	5	5
	6	3
	7	0
	7	22
	8	19
	9	17
	10	14
	11	12
	12	9
	13	7
	14	4
	15	2
	15	23
	16	21
	17	18
	18	15
	19	13
	20	10
	21	8
	22	5
	23	3
	24	0
	24	22
	25	19
	26	17

Continued.

RV Capricorni		RV Capricorni		VY Cygni		VZ Cygni		VZ Cygni	
d	h	d	h	d	h	d	h	d	h
Mar. 27	14	Mar. 31	4	(−2	14)	(−2	12)	Mar. 17	8
28	12			Mar. 4	16	(−3	6)	22	2
29	9	TX Cygni		12	13	Mar. 2	15	27	2
30	7	Mar. 13	20	20	9	7	15	31	19
		28	14	28	6	12	8	Apr. 5	19

Nomenclature of Recently Discovered Variable Stars.

Provis. Notation A. N.	Name	Position for 1900.0 R. A. h	m	s	Decl. °	′	Prec. 1900 R. A. s	Decl. ′
64.1905	SS Cassiopeiae	0	4	24	+51	0.6	+3.10	+0.33
65.1905	ST Cassiopeiae	0	12	14	49	43.9	3.16	0.33
5.1907	SW Andromedae	0	18	29	+28	50.8	3.13	0.33
—	U Tucanae	0	54	9	−75	32.4	1.86	0.32
156.1906	RZ Persei	1	23	35	+50	20.3	3.65	0.31
51.1907	SX Andromedae	1	27	34	46	0.4	3.59	0.31
33.1907	SS Persei	1	49	34	49	59.6	3.80	0.30
120.1906	RY Persei	2	38	59	47	43.3	4.01	0.26
155.1906	ST Cassiopeiae	2	43	3	68	28.5	5.28	0.25
7.1907	RV Camelopardalis	4	22	24	57	11.5	4.96	0.14
27.1907	RY Aurigae	5	11	32	+38	13.1	4.10	0.07
—	T Pictoris	5	12	19	−47	1.8	1.67	+0.07
24.1907	RW Monocerotis	6	29	18	+ 8	54.2	3.28	−0.04
3.1902	RV Monocerotis	6	53	0	6	18.0	3.22	0.08
2.1907	RU Camelopardalis	7	10	54	69	51.2	6.54	0.10
66.1907	X Leonis	9	45	40	+12	20.3	3.23	0.28
158.1906	ST Carinae	10	12	30	−59	42.9	2.04	0.30
42.1906	S Sextantis	40	29	49	+ 0	10.5	3.07	0.31
169.1906	ST Centauri	11	5	29	−51	56.8	2.67	0.32
170.1906	SU Centauri	11	6	34	47	18.0	2.74	0.33
177.1906	SV Centauri	11	43	5	60	0.5	2.90	0.33
180.1906	W Crucis	12	6	42	58	13.6	3.14	0.33
182.1906	SW Centauri	12	12	30	49	10.6	3.16	0.33
183.1906	SX Centauri	12	15	52	−48	39.4	3.18	0.33
54.1906	RV Draconis	12	33	11	+66	8.7	2.64	0.33
186.1906	X Crucis	12	40	32	−58	34.6	3.46	0.33
10.1907	RY Draconis	12	52	30	+66	32.2	2.37	0.33
141.1906	RZ Centauri	12	55	37	64	5.4	3.73	0.32
149.1906	SS Centauri	13	7	9	63	37.1	3.85	0.32
11.1907	TT Centauri	13	13.2		60	15	3.81	0.32
153.1906	U Muscae	13	18	16	64	8.4	4.00	0.31
190.1906	SY Centauri	13	35	3	61	15.8	4.05	0.31
191.1906	SZ Centauri	13	43	51	58	0.2	4.01	0.30
12.1907	ST Virginis	14	22	31	+ 0	27.1	3.07	0.27
13.1907	TU Centauri	14	28	4	−31	14.9	3.56	0.27
14.1907	RS Bootis	14	29	16	+32	11.4	2.56	0.27
86.1906	RR Bootis	14	43	15	+39	43.7	2.35	0.25
69.1905	X Lupi	14	46	45	−46	12.4	4.00	0.25
15.1907	Y Lupi	14	52.3		−54	33	4.35	0.24
67.1907	RT Bootis	15	13	22	+36	43.5	2.33	0.22
16.1907	Y Coronae	15	43	4	38	33.9	2.19	0.19
17.1907	Z Coronae	15	52.2		29	32	2.43	0.18
87.1906	RW Draconis	16	33	43	+58	2.6	1.08	0.12
50.1907	SS Ophiuchi	16	52	40	− 2	36	3.13	0.10
3.1907	SW Herculis	16	54	11	+21	42	2.56	0.09
52.1907	ST Ophiuchi	17	28	50	− 1	0.4	3.09	0.04
53.1907	SU Ophiuchi	17	34	22	+ 1	39.8	3.03	0.04
54.1907	SV Ophiuchi	17	51	25	+ 3	24.1	2.99	−0.01
55.1907	W Serpentis	18	4	6	−15	34.0	+3.44	+0.01

Provis. Notation A. N.	Name	Position for 1900.0 R. A. h	m	s	Decl. °	′	Prec. 1900 R. A. s	Decl. ′
56.1907	W Scuti	18	18	54	−13	42.5	3.40	0.03
26.1907	RZ Draconis	18	21	49	+58	50.1	0.87	0.03
57.1907	X Scuti	18	25	41	−13	10.8	3.38	0.04
58.1907	Y Scuti	18	32	36	− 8	27.2	3.27	0.05
30.1904	SY Lyrae	18	37	33	+28	43.2	2.35	0.05
61.1907	Z Scuti	18	37	36	− 5	55.1	3.21	0.05
63 1907	SZ Aquilae	18	59	35	+ 1	9.4	3.05	0.09
4.1907	Y Vulpeculae	19	0	8	24	38.3	2.48	0.09
121.1906	RX Draconis	19	1	8	58	35.2	0.96	0.09
64.1907	TT Aquilae	19	3	9	1	8.5	3.05	0.09
—	AA Cygni	20	0	46	36	32.0	2.22	0.17
193.1906	ZZ Cygni	20	20	40	46	35.7	1.92	0.19
20.1907	RS Delphini	20	24	33	15	56.5	2.76	0.20
33.1904	YZ Cygni	20	58	55	+40	53.5	2.25	0.24
48.1907	RV Aquarii	21	0	44	− 0	36.6	3.08	0.24
70.1905	RX Pegasi	21	51	44	+22	23.2	2.78	0.28
50.1906	RY Pegasi	22	1	27	33	1.2	2.64	0.29
51.1906	RZ Pegasi	22	1	29	33	1.3	2.64	0.29
23.1907	Y Lacertae	22	5	13	50	33.3	2.29	0.29
88.1906	X Lacertae	22	44	58	55	54.0	2.44	0.32
65.1907	SW Cassiopeiae	23	2	53	58	1.0	2.54	0.32
52.1906	ST Andromedae	23	43	47	35	12.5	2.96	0.33
194.1906	SV Cassiopeiae	23	34	12	51	42.5	2.88	0.33
1.1907	SV Andromedae	23	59	14	39	33.1	3.07	0 33
53.1906	SU Andromedae	23	59	28	42	59.7	3.07	0.33
154.1906	Nova Velorum	10	58	20	+53	50.9	+2.59	+0.32

Nomenclature of Recently Discovered Variable Stars—Continued

Provis. Notation A. N.	Name	Chart Place R. A. h	m	s	Decl. °	′	Magnitude Max. m	Min. m	
64.1905	SS Cassiopeiae	0	2	5	+50	45.6	9	12	v
65.1905	ST Cassiopeiae	0	9	53	49	28.9	7.5	9.0	ph
5.1907	SW Andromedae	0	16	8	+28	35.8	8.7	9.9	ph
—	U Tucanae	0	53	22	−75	40.5	9.1	13.0	ph
156.1906	RZ Persei	1	20	51	+50	6.3	8.5	9.7	v
51.1907	SX Andromedae	1	24	53	45	46.3	9.2	<11.5	ph
33.1907	SS Persei	1	46	44	49	46.1	10.7	11.2	ph
120.1906	RY Persei	2	35	58	47	31.7	8.0	10.3	v
155.1906	SU Cassiopeiae	2	39	7	68	17.0	5.9	6.3	v
7.1907	MV Camelopardalis	4	18	41	57	5.1	7 8	9.5	ph
27.1907	RY Aurigae	5	8	28	38	9.8	10.7	11.7	v
—	T Pictoris	5	11	37	−47	3.5	8.4	12.4	ph
24.1907	RW Monocerotis	6	26	50	+ 8	56.0	9.0	10.8	v
3.1902	RV Monocerotis	6	50	35	6	21.4	7	8	v
2.1907	RU Camelopardalis	7	5	59	69	55.6	8.5	9.8	ph
66.1907	X Leonis	9	43	14	+12	32.8	11.5	13.5	ph
158.1906	ST Carinae	10	11	39	−55	35.5	9.2	10.3	ph
42.1906	S Sextantis	10	27	31	+ 0	24.4	8.9	10.5	ph
169.1906	ST Centauri	11	4	23	−51	48.7	9.8	10.7	ph
170.1906	SU Centauri	11	5	26	47	9.9	8.7	9.6	ph
177.1906	SV Centauri	11	41	53	59	52.2	8.8	9.8	ph
180.1906	W Crucis	12	5	24	58	5.3	8.7	9.3	ph
182.1906	SW Centauri	12	11	11	49	2.3	8.8	11.4	ph
183 1906	SX Centauri	12	14	33	−48	31.1	8.3	10.2	ph
54.1906	RV Draconis	12	31	12	+66	23.6	9.7	<12.5	ph
186.1906	X Crucis	12	39	6	−58	26.4	8.5	9.0	ph
10.1907	RY Draconis	12	50	43	+66	46.8	6.1	7.0	v
141.1906	RZ Centauri	12	54	5	−63	57.2	8.5	8.9	ph
149.1906	SS Centauri	13	5	33	−63	29.1	8.8	10.4	ph

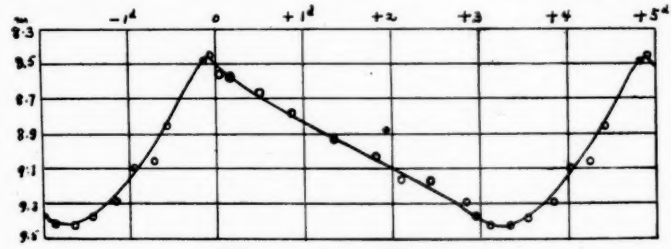
Provis. Notation A. N.	Name	Chart Place R. A. h	m	s	Decl. °	′	Magnitude Max. m	Min. m
11.1907	TT Centauri	13	11.6		−60	7	10.5	13.5 ph
153.1906	U Muscae	13	16	36	64	0.5	10.5	<14.0 ph
190.1906	SY Centauri	13	33	22	61	8.1	9.8	10.8 ph
191.1906	SZ Centauri	13	42	11	57	52.7	8.0	8.9 ph
12.1907	ST Virginis	14	20	12	0	14.9	9.1	<10.5 ph
13.1007	TU Centauri	14	26	35	−31	8.2	9.0	14.0 ph
14.1907	RS Bootis	14	27	21	+32	23.4	8.9	10.0 ph
86.1906	RR Bootis	14	41	29	+39	55.1	8.9	<12 v
69.1905	X Lupi	14	45	5	−46	6.1	10.4	12.8 ph
15 1907	V Lupi	14	50.5		−54	27	8.5	13.5 ph
67.1907	RT Bootis	15	11	37	+36	53.5	9	<11 v
16.1907	Y Coronae	15	41	25	38	42.4	8.5	10.5 ph
17.1007	Z Coronae	15	50.4		29	40	8.0	<11.0 —
87.1906	RW Draconis	16	32	55	+58	8.1	9.6	10.8 ph
50.1907	SS Ophiuchi	16	50	19	− 2	32	8.1	12 v
3.1907	SW Herculis	16	52	16	+21	46.3	12.5	14.5 ph
52.1907	ST Ophiuchi	17	26	31	− 0	58.3	10.0	11.1 ph
53.1907	SU Ophiuchi	17	32	6	+ 1	41.5	10.0	11.0 ph
54.1907	SV Ophiuchi	17	49	10	+ 3	24.7	9.7	<12.0 ph
55.1907	W Serpentis	18	1	31	−15	34.2	8.5	10.0 ph
56.1907	W Scuti	18	16	21	−13	43.7	9.3	10.4 ph
26.1907	RZ Draconis	18	21	10	+48	48.6	9.5	10.2 ph
57.1997	X Scuti	18	23	9	−13	12.4	9.5	11.0 ph
58.1907	Y Scuti	18	30	9	− 8	29.3	8.9	10.2 ph
30.1904	SY Lyrae	18	35	47	+28	40.8	10.2	11.0 ph
61.1907	Z Scuti	18	35	12	− 5	57.5	9.0	10.3 ph
63.1907	SZ Aquilae	18	57	18	+ 1	5.6	8.8	10.5 ph
4.1907	Y Vulpeculae	18	58	17	24	34.5	13.5	14.5 ph
121.1906	RX Draconis	19	0	25	58	31.3	9.3	10.2 v
64.1907	TT Aquilae	19	0	52	1	4.5	7.6	9.0 ph
—	AA Cygni	19	59	6	36	24.5	8.0	9.2 v
193.1906	ZZ Cygni	20	19	14	46	27.1	10.4	11.5 v
20.1907	RS Delphini	20	22	28	15	47.6	8.9	9·8 ph
33.1904	YZ Cygni	20	57	13	+40	42.9	—	— —
48.1907	RV Aquarii	20	58	25	− 0	47.2	8.5	<12 v
70.1905	RX Pegasi	21	49	39	+22	10.5	8.1	9.4 ph
50.1906	RY Pegasi	21	59	28	32	48.1	10.0	10.6 ph
51.1906	RZ Pegasi	21	59	30	32	48.2	10.0	12.4 ph
23.1907	Y Lacertae	22	3	30	50	20.1	8.5	9.2 v
88.1906	X Lacertae	22	43	9	55	39.8	8.2	8.6 v
65.1907	SW Cassiopeiae	23	0	59	58	46.4	9.2	10.2 ph
52.1906	ST Andromedae	23	31	33	34	57.6	8.2	<10.5 ph
194.1906	SV Cassiopeiae	23	32	2	51	27.6	7	< 9.5 v
1.1907	ST Andromedae	23	56	56	39	18.1	9	<12.5 ph
53.1906	SU Andromedae	23	57	10	+42	44.6	8.3	9.8 ph
154.1906	Nova Velorum	10	57	15	−53	42.9	—	— —

New Variable Star 178.1907 Tauri.—This was discovered by Rev. Joel H. Metcalf of Taunton, Massachusetts, on a photograph taken November 11, with two exposures of 47 and 40 minutes respectively. The plate was moved during the exposure so that the star images are lengthened out into trails. Toward the last part of the first exposure the star shows a slight increase in brilliancy and during the second exposure it increased about 0.6 magnitude. The position of the variable is approximately

1900 R. A. $3^h\ 31^m\ 24.^s1$ Decl. $+5^\circ\ 2.'5$

The nearest BD star is $+4^\circ 560$ from which it is (north following) $+12.^s4$ in R. A. and $+0.'7$ in Decl. Its magnitude is 11-12.

Variable Star V Lacertæ 110.1904.—In the Bulletin No. 13 of the Laws Observatory Mr. Seares gives observations of this variable extending



LIGHT CURVE OF V LACERTÆ 110.1904.

through the interval June 30, 1904 to August 11, 1907 and derives new elements as follows:

Maximum = J. D. 2416666.76 + 4.^{d}98269 E, (Gr. M. T.).

The light curve shows a sharp maximum with slow descent and rapid rise.

Variable Star X Lacertæ (88.1906).—In Bulletin No. 13 of the Laws Observatory Mr. Seares gives the following new elements of this variable star, depending upon a long series of photometric observations during the period September 7, 1906 to August 11, 1907.

Minimum = J. D. 2416672.45 + 5.^{d}44269 E (Gr. M. T.).

New Variable Star 179.1907 Cassiopeiæ.—This is announced in *A. N.* 4222 by Professor W. Ceraski as discovered by M. S. Blajko upon his photographs taken at the Moscow Observatory. Its position is

$\alpha = 0^h\ 44^m\ 32^s$	$\delta = +46°\ 41'.4$	(1855.0).
$= 0\ 47\ 03$	$= 46\ 56.1$	(1900.0)

About 0.′5 north of this there is a star of about magnitude 12. From the study of 25 plates it appears that the variable changes from 10.5 to 11.2 magnitude and that its period is short.

New Variable 180.1907 Aurigæ. In *A. N.* 4222 Mr. L. Pračka, of Bamberg, calls attention to the star BD 46° 1088 which appears to vary between the magnitudes 8.9 and 9.6 in a period of from 18 to 28 days. The position of the star is

$\alpha = 5^h\ 52^m\ 46^s.6$	$\delta = +46°\ 27'.0$	(1855.0)
$= 5\ 56\ 08.1$	$+46\ 27.4$	(1900.0).

New Variable Star 181.1907 Aurigæ.—This is announced by Professor W. Ceraski in *A. N.* 4225 as discovered by Mme. L. Ceraski upon the Moscow photographs. It appears to vary between the magnitudes 11 and 12.5 or fainter. Its position is

$\alpha = 4^h\ 29^m.8$	$\delta = +31°\ 03'$	(1855.0)
$= 4\ 32\ 0$	$+31\ 09$	(1900.0)

Variable Star Notes.

MIRA *o* CETI.

The unusually bright maximum of this star in the end of 1906 was not equalled this year as the highest range was but little beyond the lustre

of Gamma Ceti of 3.4 magnitude. Its customary uneven increase and decrease are noticeable in the following record.

1907 Aug.	19	8.8	magnitude.
Sept.	5	8.3	"
	12	7.5	"
	18	7.2	"
	28	7.0	Nearly equal to 71 Ceti.
Oct.	7		At low altitude, visible to naked eye. Equal to Nu Ceti.
	28		About .2 brighter than Gamma Ceti, but half a magnitude less than Alpha Ceti.
Nov.	1, 3, 7, 19, 24.		Equal to Gamma; less than Alpha: brighter than Delta.
	29		Less than Gamma; brighter than Delta.
Dec.	7		Equal to Delta, but in opera glass seems brighter than that star. Brighter than Nu Piscium.
	12		About .2 dimmer than Delta.

V CASSIOPELÆ.

This variable may be found about half a degree northeast of the sixth magnitude star numbered 2 in Flamsteed's catalogue. A recent maximum,

VICINITY OF V CASSIOPELÆ.

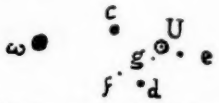
in which it attained to nearly seventh magnitude was observed as follows:

1907 Aug.	9	Equal to f.
	25	Equal to a and to b.
Sept.	1	Brighter than a or b. Less than m.
	4, 12, 15	The same.
	23	Slightly brighter than a or b.
	27, 29	Distinctly brighter than a or b.
Oct.	3, 7	The same.
	14	Equal to a and b.
	28	Less than b. Equal to f.
Nov.	2	Less than f. Equal to g.
	9, 21	Dimmer than g. Equal to n.

Some maxima of two other variables in this constellation were also observed as follows:

U CASSIOPELÆ.

1906 Aug.	12	Equal to g.
	19	Brighter than g; less than e.
Sept.	16	Brighter than d; equal to c.
	26	Brighter than e or d; less than c.
	29	Nearer to c than to d.
Oct.	3	Midway between c and d.
	6	Nearer to d than to c.
	7, 12	The same.



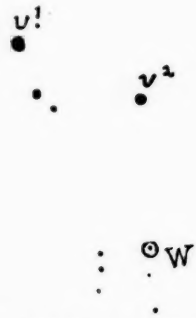
VICINITY OF U CASSIOPELÆ.

Nov.	4, 11	Equal to d; brighter than e.
	14	Equal to e; less than d.
	20	Between d and e.
1907 Aug.	8	Brighter than g; less than d: equal to e.
	25	It seems equal to e and to g. Altitude low.
Sept.	1	Less than e or g.
	4	Invisible. Night dim.

During the following three months, including some nights of more than ordinary clearness, 19 observations were taken of the vicinity of the variable but it was not discernible in a four-inch lens. As shown in the chart, it is adjacent to the star of fifth magnitude, Omicron Cassiopeiæ.

W CASSIOPELÆ.

1905 May	27	Between a and c; brighter than d. Morning very clear.
June	26	Between a and c.
July	6	The same.
Sept.	17	Equal to n; Less than d.
	24	The same.
Oct.	15	Between d and n.
	23, 26	Equal to n, less than e or f.
Nov.	3	The same.
	14	Between n and k.
	28, 20, 30	The same.
Dec.	3	Dimmer than n or k.
1906 Aug.	12, 19	Equal to c.
Sept.	16, 26	Equal to d; less than c.
Oct.	3, 6, 12	Equal to d; brighter than n.
Nov.	4. 20	Less than e or F. Equal to n.
1907 Aug.	8, 25	Brighter than d or c; less than a.
Sept.	1, 4, 12	The same.
	15	Equal to a.
	23	Less than a, brighter than c.
Sept.	29	Slightly brighter than c or d. Night clear.



VICINITY OF W CASSIOPELÆ.

Oct.	2, 7, 14	Equals d brighter than e.
	28, 30	Less than than d. Equals e.
Nov.	2, 7, 21	The same.
	24	Less than e.

The coördinates of this variable are:
R. A. $0^h\ 48^m\ 59^s$ Decl. $+58^\circ\ 09'$.

ROSE O'HALLORAN

San Francisco,
December 14, 1907.

GENERAL NOTES.

β 208 in Periastron. Please call attention to the periastron passage of β 208, which will occur early in 1908. The orbit is highly inclined and very eccentric like that of γ Andromedæ B. C., and the angle will soon change by 180°. The minimum distance will not exceed 0.″05, and it will probably be beyond the reach of any telescope in the world, but it will soon widen out again. Observations are needed just before and just after periastron passage. The orbit will then be accurately defined, while if this opportunity is neglected another will not recur for almost forty years.

T. J. J. SEE.

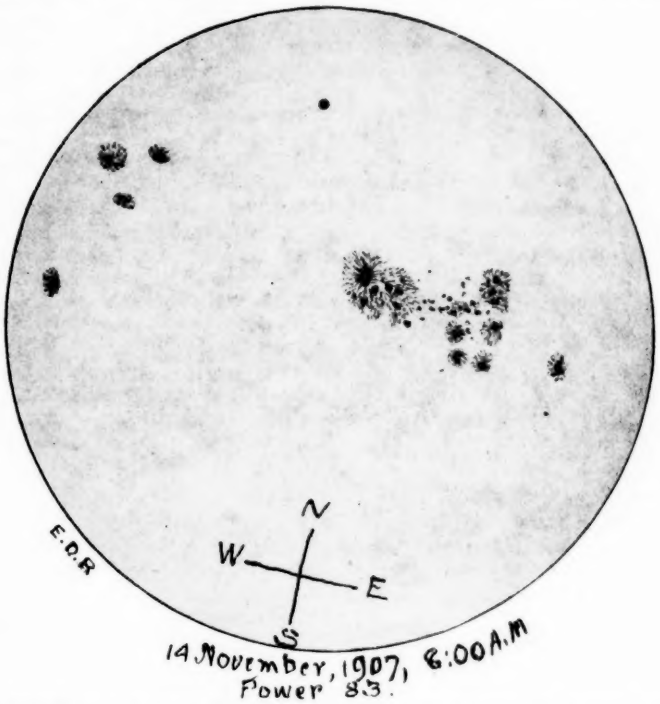
Naval Observatory.
Mare Island, California.

Bulletins of Harvard College Observatory. On page 517 of the October number of POPULAR ASTRONOMY, is given a list of different Observatory publications, prepared by Mr. Severance. Permit me to correct the list of publications credited to this observatory. The Report of the Henry Draper Memorial has been discontinued. The present publications of the observatory are:—

Annals
Annual Report of the Director
Bulletins
Circulars.

EDWARD C. PICKERING.

Sun Observations at Syracuse University. Though the morning of November 14 was somewhat cloudy here, the Transit of Mercury was visible most of the time after 7:45 A. M. to near its finish. I watched the planet until it was within about five seconds of arc of third contact. The time of third and fourth contacts could not be accurately noted as clouds prevented. During the observation I had time to make a careful and deliberate drawing of all that was to be seen on the Sun's disk. Mercury is shown



in transit as a solitary black disk slightly west of north. The drawing also shows the great sun-spot and several others. The objects on the Sun's disk are shown in approximate position on the disk as they individually appeared magnified 83 times, but the disk of the Sun is not magnified on the same scale.

E. D. Roe, Jr.

Syracuse University,
November 8, 1907.

Disappearance of Saturn's Rings Seen at Chabot Observatory—Merely to confirm reports you will probably receive, I write to say that Saturn's ring is an easy object in the 8-inch Clark equatorial of this observatory.

When the ring disappeared in the early part of October, I believed, of course, that it would remain completely invisible until January following, and

took no interest in it except the novelty of seeing Saturn without the ring. My surprise was very great then, when on Oct. 29th, the ring flashed out distinctly as a row of dots, again as a broken line, and then as a very fine but continuous line.

I made careful notes and watched carefully on succeeding nights, and soon found that I could see the ring any time when the seeing permitted the belts to be well seen. In fact, the ring could be rather more easily seen than any but the most prominent belts. Several visitors saw it without trouble. One evening when a satellite was apparently in the middle of the fine line, a visitor described it as "a piece of string with a knot in it."

The intervals when it can be distinctly seen vary from (say) a tenth of a second to two seconds.

CHARLES BURCKHALTER.

Chabot Observatory,
Oakland, Cal.,
Dec. 16, 1907.

Observations of the Transit of Mercury were made at the Harvard College Observatory this morning, under favorable atmospheric conditions. The observed times of third and fourth contact are given below in Greenwich mean time:

Date 1907	Third Contact h	m	s	Fourth Contact h	m	s	Instrument	Observer
Nov. 14,	1	48	16	1	50	47	15-in. Equatorial	O. C. Wendell
	1	48	16	1	50	26	6-in. Equatorial	L. Campbell
	1	48	9	1	50	37	5-in. Clacey	W.H.Pickering
	1	48	11	1	50	30	4-in. Caswell	J. R. Edmonds

Twenty-three photographs were obtained by Mr. E. S. King, with the 11-inch Draper Telescope.

EDWARD C. PICKERING.

Transit of Mercury, Nov. 13-14, 1907—The transit of Mercury was observed with the 12 in. equatorial stopped down to 8 in. with polarizing eyepiece magnifying 144 diameters. Clouds covered the Sun during most of the passage but broke at time of contacts which were recorded by chronograph as follows-

Seeing bad. Longitude E, $2^h\ 21^m\ 52^s.7$

I Contact	G. M. T.	$22^h\ 24^m\ 2^s.5$	(5^s late)
II "	(Geometrical)	22 25 41.1	
III "	"	1 47 44.7	
IV "		1 49 51.1	

The black drop was noted for 7 seconds after II contact and before III contact. The sun's limb was very unsteady so that the internal contacts are probably the more accurate.

ALFRED H. JOY.

Syrian Protestant College Observatory,
Beirut, Syria.

A Bright Meteor—Thinking that it might possibly interest you, I am writing this to tell you that I observed a meteor of considerable brightness yesterday. It was 5:45 p. m. (This was the time by my watch, and as I was in some doubt as to the exactness of its running, I called up the telephone office a few minutes later, and found that the watch was correct according to their time, which is considered quite accurate.) I was in the yard and was stooping to pick up some object, when I noticed that it became light about me,

and faint shadows were moving past me. I looked to the North and saw a meteor which then had come into view past the corner of a building. It moved quite slowly and thus gave me time to make my observations with some leisure. I should say that it appeared to have an elevation of 20 degrees, moved eastward and disappeared at an elevation of, I judged, five degrees; but am inclined to think that was too low an estimate, and should think seven or eight degrees possible. I have not the means of making sure instrumentally; but could get the elevation of its disappearance accurately to one degree, with a transit. It was, as stated, bright enough to cast shadows of trees and fenceposts; but decreased in brightness as it moved on. There were at least three periods at which it gave off a considerable shower of sparks; and its disappearance took place in the midst of such a shower. In this last action the sparks flew in all directions in considerable numbers. I noted well the point at which it disappeared; and have this morning made measurements and find the angle to be about 59 degrees east of north. On the map this would be somewhere in line with New Richmond, Barron, Butternut, and Mercer, Wis., and Gogebic, Brotherton, Boraga, and Keeweenaw Bay, Mich. I hardly suppose this is of any importance, except as reports might come in from other points. I suspect that no large fragments reached earth. It probably was pretty well dissipated before it could fall. Still, as it was an unusually large meteor, or bright one, (the largest but one that I have seen), possibly it may have left some trace somewhere in the way of fragments. I saw it through an arc of at least 55 degrees in its motion. How long it took it to make this distance I can not say. I had time to shift my position gradually so as to keep it directly over a post which I fixed on as a point of reference.

A. A. VEBLEN.

Stillwater, Minnesota.
Nov. 24, 1907.

Mars as the Abode of Life is the title of a carefully written paper in the November *Century Magazine* by Dr. Percival Lowell. This is the first paper of a series on "Mars as the Abode of Life," which is being prepared by Mr. Lowell. The particular theme of this paper is "The Genesis of a World," its origin, the typical meteorite, its history and meaning in world genesis, the various stages of crust formation in planet growth until advanced age ensues.

The cataclasm of which the author speaks in the early processes of world formation, is pretty strongly emphasized, as if it might be the only, or the main way, in which world existence begins. We do not think Mr. Lowell means to convey that impression, but probably, only to say that this appears to be one method in which planet life begins in its early history.

Mr. Lowell has set this introductory part in popular phrase easily to be understood, though embracing a wide range of scientific thought well related to the theme in hand.

The article is finely and fully illustrated, and, as a whole, will lead its readers to expect more with increasing interest as the series goes on. This ought to be so for no other astronomer living has studied the planet Mars more thoroughly or caused it to be studied more favorably by others than has Mr. Lowell. Astronomy owes him much for his long, earnest and patient work for the science.

Photographic Chart of the Sky—We have recently received two fasciculi of prints from the chart plates taken at the observatory of Tacubaya, Mexico. These charts are beautifully printed by the heliogravure process

upon heavy plate paper, which ought to be very durable. The star images are black and distinct, each image being triple, the result of three half-hour exposures. The components of the triple image of stars brighter than the tenth magnitude encroach upon each other but in those of the eleventh magnitude and fainter the components of the image are separated so that quite accurate positions could be measured from the prints. The faintest stars shown are of the fourteenth magnitude as indicated by a scale of magnitude printed upon the margin of the chart.

The *reseau* or reticle which was imprinted upon the original plate before its development has very distinct sharp lines. In the reproduction the squares are approximately one centimeter on a side, and the scale of the prints is noted as 1′ in declination=2 millimeters, and 1^m in right ascension=28.8 millimeters at the center of the plate. All of these charts are in the zone having as its center—16° of declination. The charts are 8^m apart in right ascension and are numbered successively in the order of right ascension. Some of the numbers are missing and will we suppose be supplied later. The numbers now at hand are: 1, 3, 9, 10, 11, 12, 13, 14, 17, 23, 24, 30, 32, 33, 34, 35, 36, 37, 38, 39, 40, 43, 44.

These charts in this way made accessible to astronomers in general will certainly be of very great value, their form is convenient for use and it seems as if doubt of the preservation of the star images was largely removed by this process.

The photographs were taken under the direction of Mr. Felipe Valle, Director of the Observatory of Tacubaya, and the printing was done by L. Schutzenberger, Paris.

Dr. Charles. A. Young, Hanover, N. H., departed this life Jan. 2, 1908. His many friends the world over, will feel the loss in the rank of great astronomers keenly. A biographical sketch of this great scholar will appear in this journal soon.

Dr. T. D. Simonton, of St. Paul, was known to many of the readers of this magazine who will regret his death which occurred late in December. Fuller notice of his interest and work in astronomy will be given later.

Jupiter's Satellites VI and VII. These diagrams are a graphical representation of the observations of Jupiter's Satellites VI and VII from photographs taken at the Royal Observatory with the 30-inch Reflector during the oppositions of 1905-6 and 1906-7, printed in the MONTHLY NOTICES vol. lxvi. p. 438 and vol. lxvii. p. 479.

During the 1905-6 opposition eighty-six photographs of J. VI were secured on thirty-six nights from 1905 August 23 to 1906 February 15—a period of 177 days. Of J. VII nineteen photographs were secured on fifteen nights from 1905 October 22 to 1906 January 26—a period of 97 days.

The opposition 1906-7 was not so favorable as regards weather conditions, but fifty-six photographs of J. VI were obtained on twenty-eight nights over a period of 222 days, and twelve photographs of J. VII on seven nights over a period of 87 days.

The positions plotted in the diagrams are the mean when more than one photograph was taken on any night. The curves were drawn through these points, but in the case of 1906-7 observations of J. VII the curve is continued beyond the observations to indicate the apparent form.

For comparison, the orbits of the four larger satellites are shown, the major axes being plotted to scale, but the minor axes intentionally exaggerated.

ASTRONOMER ROYAL.

From MONTHLY NOTICES, LXVII, No. 9.

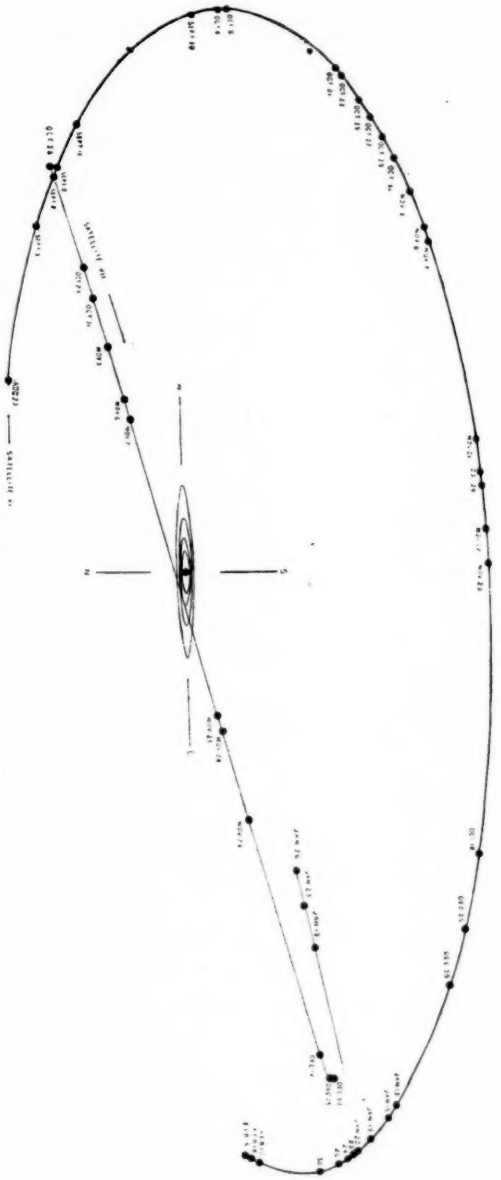


Diagram showing the positions of Jupiter's Satellites VI. and VII., from photographs taken at the Royal Observatory, Greenwich, during the Opposition 1905-6.

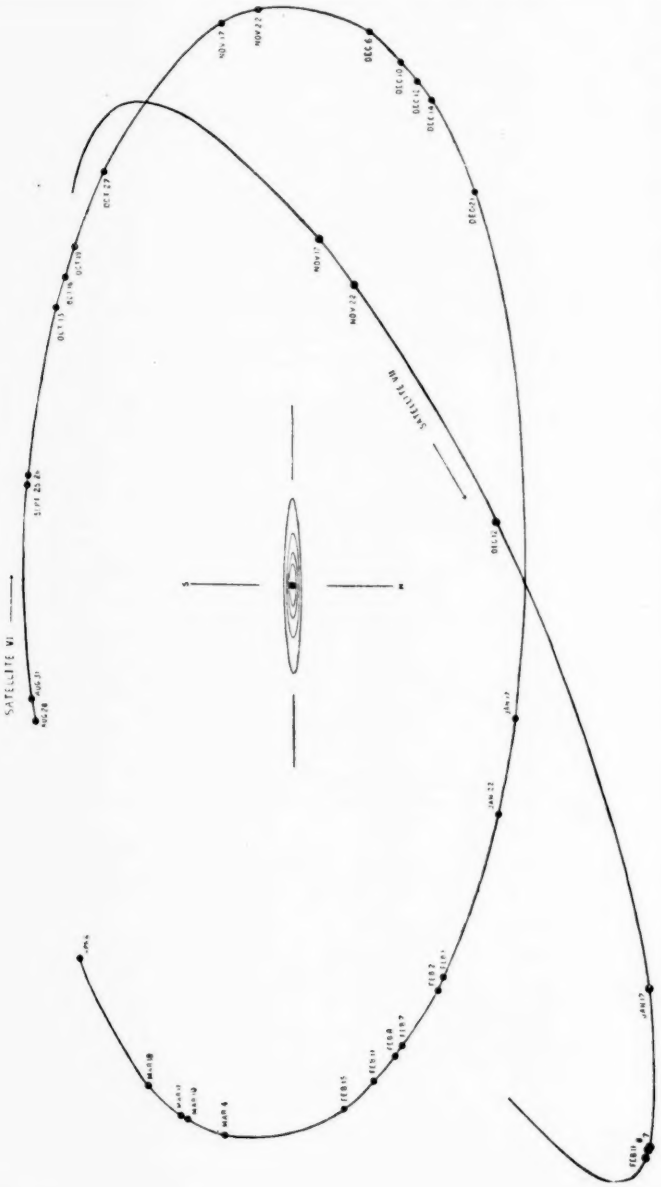


Diagram showing the positions of Jupiter's Satellites VI. and VII., from photographs taken at the Royal Observatory, Greenwich, during the Opposition 1906-7.